THESIS OF THE DOCTORAL (Ph.D.) DISSERTATION

THE IMPACT OF BIOFUEL PRODUCTION AND CONSUMPTION ON ECONOMIC EXPANSION IN THE EUROPEAN UNION

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2023

1. INTRODUCTION

1.1. Research background

Energy is a crucial part of economic progress as it is a key part of many production and consumption activities. One of the most important things for economic growth is energy. From a practical viewpoint, energy use drives financial development, economic growth and industrial productivity, and it is a key part of how any modern economy works (BHATTACHARYYA, 2019; GRIFFIN & STEELE, 2013; SAIDI, 2023; SCHWARZ, 2022; VARUN ET AL., 2009; WANG ET AL., 2021). In recent years, the energy demand has been soaring internationally (JIANG ET AL., 2023; ROBLES-IGLESIAS ET AL., 2023; SAHA ET AL., 2022). Also, energy prices are increasing daily (MACDONALD-SMITH & WIGGINS, 2022; WRIGLEY, 2022). This skyrocketing demand for energy and the soaring oil price have prompted energy-consuming nations to focus more on developing alternative energy sources (OLÁH, 2005; SULE ET AL., 2022). Biofuels are one of the most prominent alternatives to fossil fuels.

Biofuels are supported and encouraged due to their renewable and ecological benefits. There are two main categories of energy: fossil fuels and renewable resources. Renewable energy sources include the sun, biomass, wind, hydro, nuclear, geothermal, etc., while fossil fuels include oil, coal, and natural gas. As the need for energy throughout the world increases, energy scarcity has emerged as the primary obstacle to the growth of the global economy (DEMIRBAS, 2017). Incorporating biofuels will lessen a nation's dependency on conventional petroleum imports from other nations, mitigate the effects of oil price swings, boost the economy, and reduce carbon emissions. In addition, biofuels stimulate new businesses while concurrently boosting global economic activity.

As an integral part of the ‘bio-economy’ and as a source of renewable energy, biofuels have the potential to greatly enhance the safety of our energy, economic soundness, and the quality of our environment. Biomass is any dry organic matter that may be burned to produce heat or electricity; examples include wood waste, grass clippings, and farm byproducts (DEMIRBAS, 2008; THE ROYAL SOCIETY, 2008). The biofuels industry directly supported nearly 400,000 employments, with a total of 1.9 million jobs supported by the industry in the United States. By 2030, the advanced biofuel industry will have contributed $113 billion to the economy. There would be a $300 billion impact on economic activity as a whole (BIO, 2022).

Bioenergy plays a crucial part in the EU's markets for renewable energy and has the potential to significantly impact a low-carbon economy. Because they have a lower carbon footprint than other products, bio-based products are a desirable option for lowering glasshouse gas emission (BANJA ET AL., 2019). European Union is working with high importance on producing more biofuels and reducing their dependency on crude oil. That is why, EU countries' governments take different initiatives. For example, as the plenary of the European Parliament sets to vote on the revision of the Renewable Energy Directive, whether the EU will maximise the use of sustainable biofuels remains of paramount importance. There are several reasons why the EU should improve its biofuel efforts. Here are some examples, such as reducing the dependency on crude oil, promoting food security throughout the EU, fighting against adverse effects of climate change, and meeting climate targets (EU BIOFUELS CHAIN, 2022). EU commission's RePowerEU proposal also supports promoting European energy security and ensuring the sustainable domestic production of biofuels, promoting circular economy and carbon neutrality. According to one report of European Commission, 85% of Europeans think that the EU has to lessen its reliance on Russian oil and gas as soon as feasible (REPOWEREU, 2023), whereas biofuel is one of the most alternative solutions. Biofuel also have some very increasing importance in EU economy because of several forces such as rural development, energy security, investment, energy independence, and so on. Biofuel development in the EU is a relatively recent phenomenon, with significant progress made over the past 15 years since 2005. However, the current decade is the most important period for biofuel development. It is worth noting that although we refer to the EU as a single economic zone, not all countries within the region have made significant contributions to the development of biofuels (HASAN & JUDIT, 2022). Overall, biofuel also plays important roles in overall sustainability (CADILLO-BENALCAZAR ET AL., 2021)

Several studies found that the production and consumption of biofuels have a significant impact on economic growth. For example, HARTLEY ET AL. (2019A) revealed that expanding the bioethanol business to focus on a single product might boost economic growth without compromising food safety. NAKAMYA (2022) demonstrated that biofuels have the potential to provide a novel framework for alleviating poverty and promoting economic growth in economies that are heavily dependent on agriculture as their primary source of revenue. MEYER ET AL. (2013) mentioned biofuel as one of the major economic forces for the Brazilian economy. Some other studies also emphasize both production and consumption of biofuel as an importance force of financial development and economic growth (ARIMA ET AL., 2017; BANDYOPADHYAY ET AL., 2009; DATTA, 2022; DEMIRBAS, 2009; ENGLISH ET AL., 2008; FORAN, 2001; FORAN & CRANE, 2000; GEHLHAR ET AL., 2012; MOSCHINI ET AL., 2012; SAIDI, 2023; WANG ET A., 2021; EREN ET AL., 2019).

1.2. Research gaps and questions

Empirical research on the contribution of biofuel production and consumption to economic growth is lacking. Also, the relationship between bioeconomy and financial development is not greatly explored in the literature. Considering the EU as a study area, there is still a lack of literature. There is little research on the economic significance of biofuels in the EU. Considering the above significance and gaps of this research, I specify five research questions (RQ) in the following section:

- *RQ1: How does the production of biofuels impact on economic growth in the EU?*
- *RQ2: How does the consumption of biofuels impact on economic growth in the EU?*
- *RQ3: How does the degree of impact of biofuel production differ from its consumption in the EU?*
- *RQ4: How does biofuels, financial development, and economic growth cause each other in the EU?*
- *RQ5: How does bio-economy impact financial development, and vice versa?*

The answer of these five research questions is experimented in the finding section separately. Also, the output of these five questions are discussed in the discussion sections.

1.3. Objectives of this study

This study identifies five research objectives based on research gaps and research questions.

- *First objective* - to examine the empirical impact of biofuel production on economic expansion in the EU.
- *Second objective* - to investigate biofuel consumption's empirical impact on EU economic expansion.
- *Third objective* - to explore the relative importance of the impact of biofuel production on biofuel consumption in the EU.
- *Fourth objective* - to investigate the causal relationship between biofuel variables, financial development, economic growth.
- *Fifth objective* – to investigate impact of bio-economy on financial development, and vice versa.

1.4. Research hypotheses

The hypotheses are mentioned in the following sections.

Hypothesis 1		*Biofuel production has a significant positive impact on EU economic growth.*
Hypothesis 2		*Biofuel consumption has a significant positive impact on EU economic growth*
Hypothesis 3		*Biofuel production has a higher significant positive impact compared to biofuel consumption on EU economic growth.*
Hypothesis 4	4A	*Biofuel production causes financial development and EU economic growth.*
	4B	*Biofuel consumption causes financial development and EU economic growth.*
Hypothesis 5		*Biofuel production and consumption has positive impact on financial development, and vice versa.*

All hypotheses are experimented here in this study as separate sections.

1.5. Research design

In this research, an extensive analysis has been carried out to examine various previous scholarly works that have explored the concepts of biofuels, biofuel production, biofuel consumptions, and overall bioeconomy and its impact on EU economy. I design the research considering the concepts of this study. Initially this research was designed based on number of steps.

Step 1 – After an initial review of the existing literature on the sustainable biofuel economy, I initially specify a general area of research.

Step 2 – the field of study designated now is specific, so I start exploring an extended literature review from three different aspects. First, I explore the current state of the EU bioeconomy (please see section *2.2 – Present landscape of bioeconomy in the EU*), and second, I try to conduct a bibliometric review of a sustainable biofuel economy (please see section *2.3 – Bibliometric review on Sustainable biofuel economy*), from which I find important links between biofuels and the economy. In the third phase, I focus on the empirical literature focusing on the impact of biofuels on economic growth (please see the empirical findings of this study).

Step 3 – I specify the study area, EU, the research gap based on study area, research question focusing on study gap, objectives aligning with research gap & questions, and finally hypotheses formation.

Step 4 – I specify the methodological structure of the study based on previous literature.

Step 5 – Based on methodology and estimated model, I collect secondary data and processed for the experiment analysis.

Step 6 – Using the collected data, I experiment with the specified models from the methodology section.

Step 7 – After finalizing the experiment and getting the output in hand, I analyze the output of the study.

Step 8 – After the findings and analysis, I evaluate the study hypotheses that I assumed in the third step.

Step 9 – After evaluating research hypotheses, I address research gaps, questions, and research objectives based on experimental output.

Step 10 – Finally, I start writing the thesis report according to university pre-specified doctoral thesis regulation and structure.

The step-by-step research design is mentioned in Figure 1.

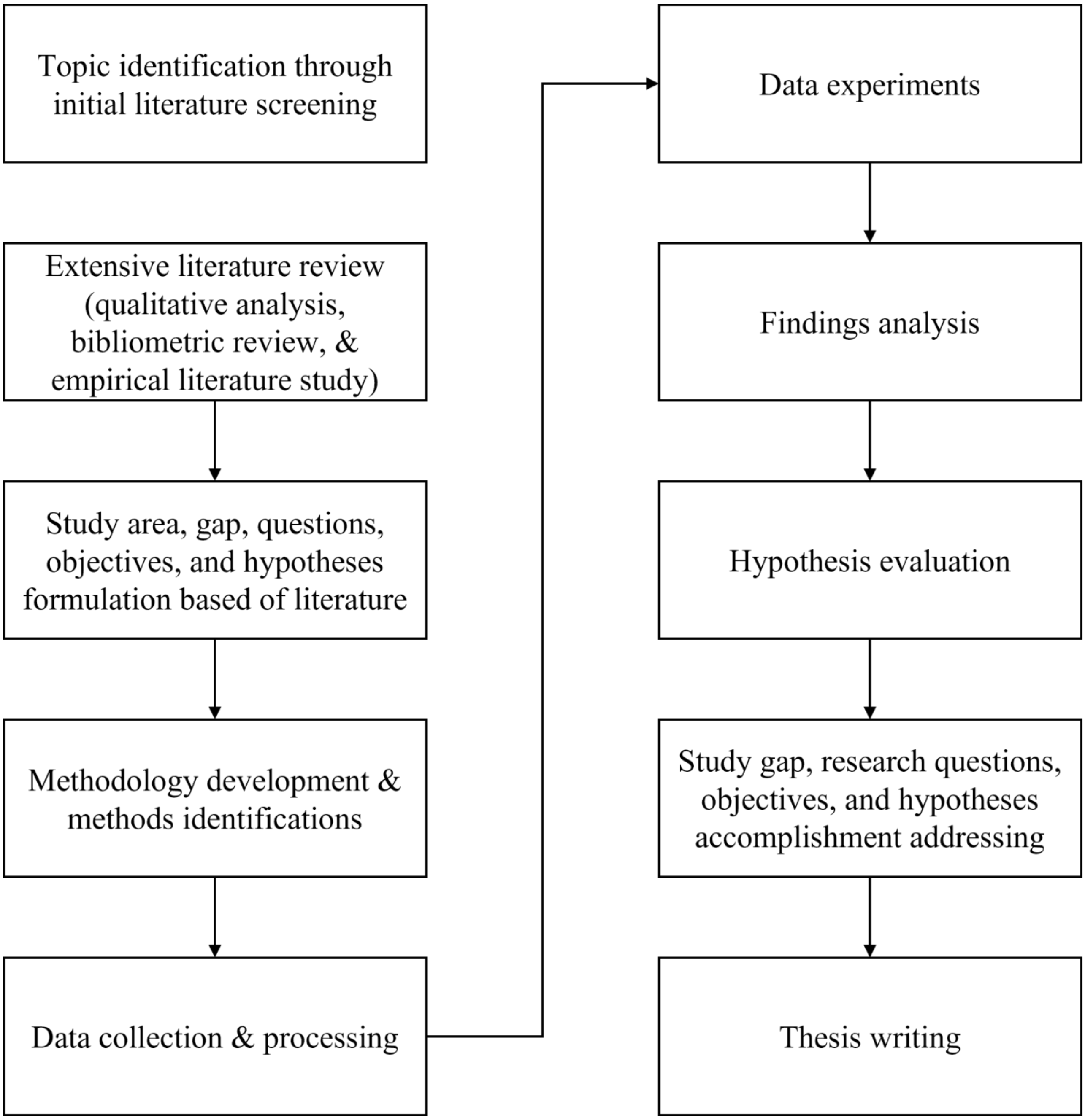

Figure 1: Research design

Source: Author’s illustration (2022)

1.6. Structure of the thesis

This thesis is presented in a structured way. There are six key sections of the thesis. These are the introduction, literature review, data and methodology, findings and analysis, conclusion and policy implications, and novel findings and contributions.

In the first section, Introduction, this study presents the study background and significance, the research gap, five research questions, five research objectives, five study hypotheses, research design, and finally, the structure of the thesis. This section mainly gives the overall significance and aims of the study.

In the second section of the dissertation, the literature review, this study includes four sub-sections. First sub-section, this study discusses the definition of biofuels, explore the generations of biofuels, and different types of biofuels, and benefits and disadvantages of biofuels. Second sub-section, the present status of biofuel production and consumption in the European Union. More particularly, EU biofuel production, the consumption of ethanol feedstock, the share of most renewable energy consumption, and the contribution of biofuels for transport in the EU. This section helps to understand the overall EU bioeconomy scenario. Third sub-section, the bibliometric findings on biofuels. More precisely, yearly scientific output, national scientific output and collaboration, top-cited nations, most-used sources, top-relevant phrases, research priorities and the expansion of the biofuel economy, co-occurrence evaluation, and conceptual structure map. This section helps to understand the overall dimensions of bioeconomy and in what aspect biofuels connect economy. Fourth sub-section, the hypotheses of the study. Here, the first hypothesis is assumed from the previous literature on the production of biofuel's impact on economic growth. The second hypothesis is assumed from the previous literature on the consumption of biofuel impact on economic growth. The third hypothesis is biofuel production has a higher significant positive impact compared to biofuel consumption on EU economic growth. The fourth hypothesis is assumed from the previous literature on the causality between production and consumption of biofuel and economic growth.

In the third section, this study presents the data and methodology. The first section presents how and what types of data were used in this study and the measurement of the study variables. The second section presents the model construction of the study. The third and fourth section include the methods of unit root test and panel cointegration tests. Fifth, this study presents which panel regressions are used to investigate the output of the study in the sixth section.

In the fourth section, the findings and analysis are presented. Particularly, the findings and analysis section also have six subsections. The first section presents the descriptive statistics (description of the production and consumption of variables, descriptive statistics, and unit root tests). The second section shows the output of hypothesis 1 (impact of biofuel production on economic growth). Third, third section shows the output of hypothesis 2 (impact of biofuel consumption on economic growth). Fourth, investigation of both production and consumption of biofuels in a single model (Hypothesis 3). Fifth section presents the panel granger causality relationship (Hypothesis 4). Section six presents nexus relationships between biofuel production and consumption, financial development, and economic growth (Hypothesis 5). Finally, seventh section presents the hypotheses evaluation of the study.

In the fifth section, conclusions and policy implications, presents conclusion, limitations of the study, future research directions, and policy implications.

In the sixth section, I present novel findings and contributions. There are six novel contributions of this study. These contributions are aligned to the questions, objectives, and hypotheses of the study.

After the sixth section, I present the list of figures, tables, references, list of publications, statements, acknowledgments, and an appendix of the study. In the appendix, I present all the extensions and detailed findings of the study.

2. Hypotheses development

2.1.1. Biofuel production and economic growth

Biofuel production impact is connected in the literature with economic growth and other related forces. This literature review section discusses the previous study on biofuel production and economic growth. For example, HASAN (2022), AL-MULALI (2015), QIAO ET AL. (2016), SIEVERS & SCHAFFER (2016), MAKUTENAS ET AL. (2018), HARTLEY ET AL. (2019B), ASHWATH & KABIR (2019), HARTLEY ET AL. (2019A), MALODE ET AL. (2021), SUBRAMANIAM & MASRON (2021), and OLÁH & POPP (2022) discuss the relationship between biofuel production and economic growth. Some other studies show how other renewable energy production impact on economic growth. For example, KAZAR & KAZAR (2014), SINGH ET AL. (2019), and DINÇ & AKDOĞAN (2019) show the impact of renewable energy production on economic growth.

The above literature and empirical justification help this study assume Hypothesis 1 as follows.

Hypothesis 1: Biofuel production has a significant positive impact on EU economic growth.

2.1.2. Biofuel consumption and economic growth

Number of previous studies investigate the impact of the consumption of biofuel on economic growth and other related forces. This literature review section focuses the previous study on biofuel consumption and economic growth. OZTURK & BILGILI (2015), AL-MULALI ET AL. (2016), BILDIRICI (2017), BOUTABBA & AHMAD (2017), KOENGKAN (2017), SIMIONESCU ET AL. (2019), SIMIONESCU ET AL. (2017), and AZAM (2020) discuss the relationship between biofuel consumption and economic growth. Some other studies show how other renewable energy consumption impact on economic growth. For example, APERGIS & PAYNE (2010B), LIN & MOUBARAK (2014), and YILDIRIM ET AL. (2012) show the impact of renewable energy consumption on economic growth.

The above circumstances and empirical justification help this study assume Hypothesis 2 as follows.

Hypothesis 2: Biofuel consumption has a significant positive impact on EU economic growth.

This study has already assumed two individual hypotheses for biofuel production's impact and biofuel consumption's impact on EU economic growth. As the existing literature supports the concepts of energy production and consumption impact on economic growth, this study assumes another hypothesis adding both production and consumption of biofuels in a single hypothesis to show the relative significance, Hypothesis 3.

Hypothesis 3: Biofuel production has a higher significant positive impact compared to biofuel consumption on EU economic growth.

2.1.3. Biofuel production and consumption cause economic growth

There are many previous studies investigate the causal relationship between the energy production and consumption with economic growth. This literature review section focuses the previous study on the energy production and consumption with economic growth. In recent studies, AJMI & INGLESI-LOTZ (2020), OZCAN & OZTURK (2019), TRAN ET AL. (2022), KAZAR & KAZAR (2014), DINÇ & AKDOĞAN (2019), LISE & MONTFORT (2007), AL-MULALI ET AL. (2016), SALAMALIKI & VENETIS (2013), LIN & MOUBARAK (2014) examine the association between the consumption of renewable energy and economic expansion. Some other studies also experiment with the causality among renewable energy consumption as well as economic prosperity in several other countries and geopolitical zone, for example, Turkey (OCAL & ASLAN, 2013), OECD (AYDIN, 2019), low and lower-middle-income economies (NARAYAN & DOYTCH, 2017), Nepal (KHATRI & PAIJA, 2022), South Asia (RAHMAN & VELAYUTHAM, 2020), and so on. Correspondingly in renewable energy production aspects, CHEN, WANG, & ZHONG (2019), VURAL (2021), CERDEIRA BENTO & MOUTINHO (2016), and DINÇ & AKDOĞAN (2019) investigate the causal connection between the production of renewable energy. Based on the above previous literature, I assume another hypothesis, Hypothesis 4 (two-subsection).

Based on the above previous literature, I assume another hypothesis, Hypothesis 4 (two-subsection).

- *Hypothesis 4A: Biofuel production causes financial development and EU economic growth.*
- *Hypothesis 4B: Biofuel consumption causes financial development and EU economic growth.*

2.1.4. Biofuel production, consumption, and financial development

SAIDI (2023), WANG et al. (2021), EREN (2019) discussed the nexus relationship between bioeconomy, and financial development. Based on the above previous literature, this study assumes another hypothesis, Hypothesis 5.

- *Hypothesis 5: Biofuel production and consumption has positive impact on financial development, and vice versa.*

3. DATA AND METHODOLOGY

3.1. Data of the study

This study used annual panel data for the experiments. Biofuel production and consumption data are not available before 2000 for most countries. Even in some other countries, there is no data available before 2009. However, considering the data availability in the European Union zone, I have found Austria, Belgium, Germany, Spain, Finland, Italy, France, Netherlands, Portugal, and Sweden. Basically, the study focuses on those EU countries that has significant biofuel production capabilities. The specific study area is mentioned in the following Figure 2.

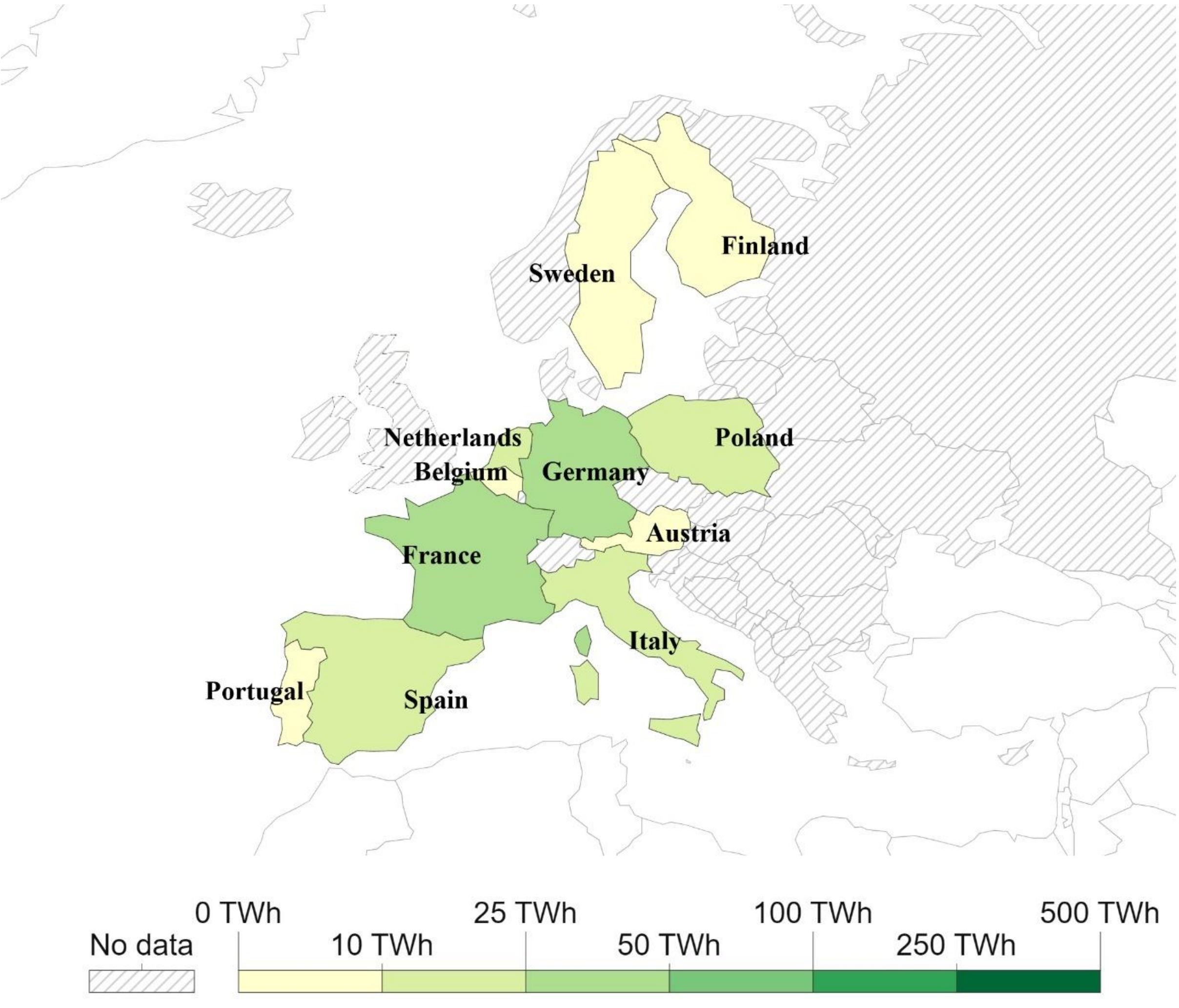

Figure 2. Study area (biofuel producing countries in EU)

Source: Our World in Data (2022)

All countries have available data on biofuel production and consumption from 2001 to 2019 except for Belgium (data available from 2008-2019), Netherlands (data available from 2004-2019), and

Portugal (data available from 2006-2019). The details of the data are mentioned in the following Table 1.

Table 1: Variable measurement

Variables	Measure	Sources
GDP	(Constant 2015 US$)	The World Bank Database, 2022
Gross capital formation	(Constant 2015 US$)	The World Bank Database, 2022
Labour force	Total labour force (Constant 2015 US$)	The World Bank Database, 2022
Financial development	Domestic credit to private sector	The World Bank Database, 2022
Biofuel Production	Biofuels Production – Mb/d - Total	Energy Information Administration, 2022
Biofuel Consumption	Biofuels Consumption – Mb/d - Total	Energy Information Administration, 2022

Source: Author's explanation (2022)

3.2. Model construction

The aggregated production function is given in the following section.

$$GDP_{it} = f(CAPITAL_{it}, LABOUR_{it}, FINDEV_{it}, BIOFPRO/BIOFCON_{it})$$

Later, based on the above concept, this study transforms the model into a logarithmic structure that is mentioned in the following section

$$(1)\ LnGDP_{it} = LnCAPITAL_{it} + LnLABOUR_{it} + LnFINDEV_{it} + LnBIOFPRO_{it} + e_{it}$$

$$(2)\ LnGDP = LnCAPITAL_{it} + LnLABOUR_{it} + LnFINDEV_{it} + LnBIOFCON_{it} + e_{it}$$

$$(3)\ LnGDP = LnCAPITAL_{it} + LnLABOUR_{it} + LnFINDEV_{it} + LnBIOFPRO_{it} + LnBIOFCON_{it} + e_{it}$$

Here, *i* LnCAPITAL refers to the log of gross capital formation, LnLABOUR refers to the log of total labour forces, LnFINDEV refers to the domestic credit to private sector, LnBIOFPRO refers to the log of biofuel production including bioethanol production and biodiesel production, LnBIOFCON refers to the log of biofuel consumption including bioethanol consumption and biodiesel consumption.

3.3. Panel unit root test modelling

This study conducts panel unit root for all the variables. The concept of unit root test for this study has been taken from the study APERGIS & PAYNE (2010A, 2010B) that shows both IM, Pearson, and Shin test done by IM ET AL. (2003) and ADF unit root test done by DICKEY & FULLER (1979). In the unit root test, this study assumes the null hypothesis is there is a unit root, and the alternative hypothesis is data is stationary.

3.4. Panel cointegrated test

This study also investigates cointegration relationship for each three estimated models. Based on the, this study also investigates cointegration relationship for each three estimated models.

(1) $LnGDP_{it} = \alpha_{it} + \delta_i t + \beta_{1i} LnCAPITAL_{it} + \beta_{2i} LnLABOUR_{it} + \beta_{3i} LnFINDEV_{it} + \beta_{4i} LnBIOFPRO_{it} + e_{it}$

(2) $LnGDP_{it} = \alpha_{it} + \delta_i t + \beta_{1i} LnCAPITAL_{it} + \beta_{2i} LnLABOUR_{it} + \beta_{3i} LnFINDEV_{it} + \beta_{4i} LnBIOFCON_{it} + e_{it}$

(3) $LnGDP_{it} = \alpha_{it} + \delta_i t + \beta_{1i} LnCAPITAL_{it} + \beta_{2i} LnLABOUR_{it} + \beta_{3i} LnFINDEV_{it} + \beta_{4i} LnBIOFPRO_{it} + \beta_{5i} LnBIOFCON_{it} + e_{it}$

Here, the α_{it} as well as δ_i allow for the probability of industry-specific fixed effects and deterministic trend, respectively. The second cointegration test conducted here is Kao Residual Cointegration Test (KAO, 1999). Here, for both tests, I assume the '*Null Hypothesis: No cointegration*' and *"Alternative Hypothesis: There is a cointegrated relationship."*

3.5. Experimental model selection

This study mainly considers both unit root test and panel cointegrated test output. Considering the output of the panel co-integrated test, this study considers the experiment the cointegrated panel regression, more particularly Panel Fully Modified Least Squares (FMOLS) and later compares the result with another panel cointegrated model, Panel Dynamic Least Squares (DOLS) models (PEDRONI, 2001; PEDRONI, 2004). These models are also appropriate when the number of observations is less than the times. Many previous studies also conducted these two models in the above circumstances (AL-MULALI, 2015; APERGIS & PAYNE, 2010B; KAYHAN & ÖZDEMIR, 2021; KHAN ET AL., 2019; N. SINGH ET AL., 2019).

4. FINDINGS AND ANALYSIS

4.1. Descriptive findings and statistics

4.1.1. Descriptive statistics

The descriptive statistic of this study is mentioned in the following Table 2. Here, all countries' descriptive statistics are presented. I present the mean, median, maximum (Max), minimum (Min), standard deviation (Std.Dv), Skewness, Kurtosis, Jarque-Bera, Probability and the number of observations of each country.

Table 2: Descriptive statistics

Stat	LnGDP	LnCAPITAL	LnLABOUR	LnFINDEV	LnBIOPRO	LnBIOCONL
Mean	6.5865	5.0440	2.3955	6.4553	2.1242	2.1401
Median	6.2590	4.8183	2.2227	6.4496	2.2258	2.3086
Maximum	8.1888	6.6430	3.7921	8.0837	4.3568	4.4005
Minimum	5.2696	3.3563	0.9587	3.6223	-2.9957	-3.9120
Std. Dev.	0.9109	0.9162	0.9158	1.0408	1.4312	1.5346
Skewness	0.2664	0.1792	-0.0399	-0.1301	-0.7871	-1.0541
Kurtosis	1.6874	1.8222	1.4919	-0.9549	3.7980	4.7623
Obs	194	194	194	194	194	194

Source: Author experiment (2022)

4.1.2. Unit root test statistics

Table 3 presents the unit root test result. I experiment with the unit root at level I (0) and the first difference I (1). In most cases, the variables are non-stationary, indicating there is a unit root. More particularly, GDP, capital formation, labour are non-stationary variables in I (0); however, biofuel production shows significance at both I (0) and I (1). This significant output indicates that biofuel production is stationary in both the level and first difference. In the case of biofuel consumption, it shows insignificant at I (0) and significant at I (1) in ADF - Fisher Chi-square output. Considering the above circumstances, I move forward with the cointegration test to decide on further experiment modelling. More particularly, except for biofuel production, all variables are non-stationary at I(0). Thereby, I am considering proceeding with the panel cointegration test.

Table 3: Unit root test

Variables	lm	ADF - Fisher Chi-square
LnGDP	2.1482	9.2189
ΔLnGDP	-4.7964***	65.5402***
LnCAPITAL	0.2639	16.5662
ΔLnCAPITAL	-7.1084***	93.8294***

LnLABOUR	0.8011	22.2541
ΔLnLABOUR	-4.2816***	59.5353***
LnFINDEV	-2.8163***	47.3372***
ΔLnFINDEV	-1.9311**	34.0323**
LnBIOFPRO	-2.5258***	41.2788***
ΔLnBIOFPRO	-3.6859***	52.1074***
LnBIOFCON	-1.7345***	29.9191
ΔLnBIOFCON	-1.5210**	31.5921*

Source: Author experiment (2022) (Note: Δ refers to first difference unit root test)

4.2. Impact of biofuel production

4.2.1. Panel cointegration test (production model)

Table 4 presents the *Pedroni Residual Cointegration Test* for the biofuel production model. I test within-dimension, weighted statistic (PEDRONI 1999; PEDRONI 2000; PEDRONI 2004), and alternative hypothesis: individual AR coefficient (between-dimension). Table 4 presents seven test statistics, such as v-Statistic, rho-Statistic, PP-Statistic, ADF-Statistic, Group rho-Statistic, Group PP-Statistic, and Group ADF-Statistic. According to Table 4, (i) v-Statistic, PP-Statistic, ADF-Statistic of within dimension show significant value, (ii) PP and ADF-Statistic of weighted statistics, and (iii) Group PP-Statistic and ADF-Statistic of between dimension show significant values, which indicate null hypothesis is rejected and there is cointegrated relationship exist in the estimated equation.

Table 4: Pedroni Residual Cointegration Test (production model)

Alternative hypothesis: common AR coefs. (within-dimension)		
Tests	**Statistic**	**Weighted Statistic**
Panel v-Statistic	1.6487**	0.1425
rho-Statistic	0.5753	1.1618
PP-Statistic	-2.6979***	-1.8024**
ADF-Statistic	-2.8350***	-2.1457**
Alternative hypothesis: individual AR coefficient (between-dimension)		
Group rho-Statistic	2.4519	
Group PP-Statistic	-4.1303***	
Group ADF-Statistic	-3.9025***	

Source: Author experiment (2022)

To show the robustness of the output of the panel cointegration test in Table 4, I also conduct *Kao Residual Cointegration Test*. Table 5 presents the output of *the Kao Residual Cointegration Test*. Here, the null hypothesis is there is no cointegration. According to the ADF statistics, the t-statistics is significant (the coefficient is -2.4120), and that support rejects the null hypothesis. Therefore, the Kao Residual Cointegration Test shows that the variables are cointegrated.

Table 5: Kao Residual Cointegration Test (production model)

Statistics	**t-Statistic**
ADF	-2.4120***

Source: Author experiment (2022)

4.2.2. Cointegrated regressions (production model)

After the unit root and panel cointegration tests, I find a cointegration relationship in the estimated model. That is why I follow the cointegrated panel regression methods. Table 6 shows the regression output of the biofuel production model. Here, the study experiments are performed on FMOLS and DOLS regression. These two models are used widely to experiment with regression when cointegrated relationships exist.

According to Table 6, capital formation is positively significant on GDP. Compared with the FMOLS model, DOLS shows a slightly higher impact of capital formation on economic growth in selected European countries. The coefficient in the FMOLS model is 0.3827 at the 99% confidence level. This positive output means that a 1% increase in the capital formation increases GDP by 0.3827% (FMOLS). The result of this section supports existing literature output. Capital formation is also grossly discussed in the literature with a significant impact on economic growth. For example, SINGH ET AL. (2019) conducted multivariate studies based on developed and developing countries' samples in renewable energy production and economic growth nexus relationship. They revealed gross capital formation significantly promotes economic growth. More particularly, a 1% surge in capital formation surges 0.44% in GDP. Labour also has a positive effect on the economy. A 1% increase in labour increases GDP by 0.4013% (FMOLS). Our result also supports the findings from the previous study. For example, SINGH ET AL. (2019) revealed a significant positive relationship between labour forces and economic growth. Particularly, 1% increase in labour force raises GDP by 0.27% for all countries, 0.31% for developed countries, and 0.23 for developing countries. Financial development is also significantly impact on economic growth (coefficient 0.0606) at the 99% confidence level. After integrating the financial development with production and consumption of biofuel variables, the result shows significant but little bit lower significance that is acceptable. More specific output is discussed in the following section.

The most important variable in this biofuel production model is the effect of biofuel production on economic expansion. Biofuel production is also very significant in the FMOLS models. A 1% growth in biofuel production surge in 0.0185% GDP growth (FMOLS). Some other studies also support the result of the study. For example, HASAN (2022), AL-MULALI (2015), QIAO ET AL. (2016), KAZAR & KAZAR (2014), DINÇ & AKDOĞAN (2019), and SINGH ET AL. (2019).

Table 6: Panel Fully Modified Least Squares (FMOLS) (production model)

Variable	FMOLS
LnCAPITAL	0.3827***
	(0.0297)
LnLABOUR	0.4013***
	(0.1138)
LnFINDEV	0.0606***
	(0.0187)
LnBIOFPRO	0.0185***
	(0.0044)
R-squared	0.9988
Adjusted R-squared	0.9987
S.E. of regression	0.0324
Durbin-Watson stat	0.3376
Mean dependent var	6.5967
S.D. dependent var	0.9095
Sum squared residual	0.1762
Long-run variance	0.0016

Source: Author experiment (2022)

This study tests another experiment for the production model that investigates the impact of biofuel production on EU economic growth. The output of another well-known cointegrated regression, DOLS model, is mentioned here in Table 7.

Table 7: DOLS model (Production model)

Variable	
LnCAPITAL	0.4386***
	(0.0380)
LnLABOUR	0.1182
	(0.1277)
LnFINDEV	0.0406*
	(0.0234)
LnBIOFPRO	0.0272***
	(0.0070)
R-squared	0.9999
Adjusted R-squared	0.9999
S.E. of regression	0.0066
Mean dependent var	6.5865
S.D. dependent var	0.9109
Sum squared residual	0.0028
Long-run variance	0.0002

Source: Author experiment (2022)

According to Table 7, the output of FMOLS model for capital formation has also high significance in DOLS model. The coefficient is 0.4386, which means that a 1% increase in the capital formation increases GDP by 0.4386% in selected European countries' economic growth. Financial development is also significant in DOLS model. Biofuel production is also very significant in DOLS model. A 1% growth in biofuel consumption increase GDP by 0.0272%. Therefore, this study confirms the robustness of FMOLS model for the impact of biofuel production on the economic growth in the panel region.

4.3. Impact of biofuel consumption

4.3.1. Panel cointegration test (consumption model)

Table 8 presents the Pedroni Residual Cointegration Test for the biofuel consumption model. I test within-dimension, weighted statistic (PEDRONI 1999; PEDRONI 2000; PEDRONI 2004), and alternative hypothesis: individual AR coefficient (between-dimension). Here I also assume the '*Null Hypothesis: No cointegration*'. According to Table 8, (i) v-statistics, PP-Statistic and ADF-Statistic of within dimension show significant value, and (ii) PP-Statistic and ADF-Statistic of weighted statistics show significant value, and (iii) Group PP-Statistic and Group ADF-Statistic of between dimension show significant values, which indicate null hypothesis rejected and there is cointegrated relationship exist in the estimated equation.

Table 8: Pedroni Residual Cointegration Test (consumption model)

Alternative hypothesis: common AR coefs. (within-dimension)		
Tests	**Statistic**	**Weighted Statistic**
v-Statistic	1.6453**	-0.3492
rho-Statistic	0.8438	1.2424
PP-Statistic	-5.3723***	-2.5325***
ADF-Statistic	-5.8389***	-3.7481***
Alternative hypothesis: individual AR coefficient (between-dimension)		
Group rho-Statistic	2.6402	
Group PP-Statistic	-4.8963***	
Group ADF-Statistic	-5.2594***	

Source: Author experiment (2022)

Following the same strategy of the biofuel production model, I also conduct the Kao Residual Cointegration Test to show the robustness of the panel cointegration test of the consumption model. Table 9 present the output of the *Kao Residual Cointegration Test*. Here, the null hypothesis is there is no cointegration. According to the ADF statistics, the t-statistics is significant (-2.5093***), which supports rejecting the null hypothesis. Therefore, the *Kao Residual Cointegration Test* shows the variables are cointegrated.

Table 9: Kao Residual Cointegration Test (consumption model)

Statistics	**t-Statistic**
ADF	--2.5093***

Source: Author experiment (2022)

4.3.2. Cointegrated regressions (consumption model)

Table 10 shows the regression output of the biofuel consumption model. Here, I also experiment the FMOLS regression. According to Table 10, capital formation is also very significant, and the coefficient is positive (0.4010). This output means that a 1% increase in the capital formation increases GDP by 0.4010%. The output of this study supports the output of previous literature that experiments with the energy consumption economic nexus. For example, AL-MULALI ET AL. (2016) investigated both the long-run and short-run effects of bioethanol consumption and capital formation on economic performance in Brazil. According to the findings, both capital formation and ethanol consumption are favorably related to economic growth. They reveal that if capital formation rises by 100%, then it will improve the country's economic progress by 13.9%.

Labour also has a positive impact on the economy in the consumption model. A 1% increase in labour increases GDP by 0.4879%. In terms of both labour forces and gross capital formation, APERGIS & PAYNE (2010B) revealed that both two variables have a significant positive impact on both short- and long-term economic growth. Financial development is also significantly impact on economic growth (coefficient 0.0579) at the 99% confidence level in the biofuel consumption model.

The most important variable in the biofuel consumption model is the effect of biofuel consumption on economic expansion. Similar to biofuel production, biofuel consumption is also very significant in FMOLS. This output supports the output of AL-MULALI (2015), AL-MULALI ET AL. (2016), APERGIS & PAYNE (2010B), and LIN & MOUBARAK (2014). Therefore, biofuel consumption also has a significant impact on the economic growth of the panel region.

Table 10: FMOLS (consumption model)

Variables	**FMOLS**
LnCAPITAL	0.4010***
	(0.0313)
LnLABOUR	0.4879***
	(0.1084)
LnFINDEV	0.0579***
	(0.0206)
LnBIOFCON	0.0115***
	(0.0039)

R-squared	99%
Adjusted R-squared	0.9986
S.E. of regression	0.0345
Durbin-Watson stat	0.3930
Mean dependent var	6.5967
S.D. dependent var	0.9095
Sum squared residual	0.2005

Source: Author experiment (2022)

This study tests another experiment for the consumption model that investigates the impact of biofuel consumption on EU economic growth. The output of another well-known cointegrated regression, DOLS model, is mentioned here in Table 11.

Table 11: DOLS model (Consumption model)

Variables	**DOLS**
LnCAPITAL	0.4561***
	(0.0474)
LnLABOUR	0.1220
	(0.2107)
LnFINDEV	0.0697
	(0.0488)
LnBIOFCON	0.0178***
	(0.0076)
R-squared	99%
Adjusted R-squared	0.9999
S.E. of regression	0.0070
Mean dependent var	6.5865
S.D. dependent var	0.9109
Sum squared residual	0.0032

Source: Author experiment (2022)

According to Table 11, it can be seen that the output of FMOLS model for capital formation has also high significance with DOLS model. However, coefficient is higher in DOLS model (0.4561). This output means that a 1% increase in the capital formation increases GDP by 0.4561% in selected European countries' biofuel energy consumption-economic growth model. Somehow, labor and financial development is insignificant here in DOLS. However, biofuel consumption is also very significant in DOLS models. A 1% growth in biofuel consumption increase GDP by 0.0178%. Therefore, this study confirms the impact of biofuel consumption on the economic growth of the panel region.

4.4. Impact of biofuel production and consumption

4.4.1. Pedroni residual cointegration test (combined model)

Table 12 presents the Pedroni Residual Cointegration Test for the model that includes both the production and consumption of biofuel I test within-dimension, weighted statistic (PEDRONI 1999; PEDRONI 2000; PEDRONI 2004), and alternative hypothesis: individual AR coefficient (between-dimension). Here I also assume the '*Null Hypothesis: No cointegration*'. According to Table 12, (i) PP-Statistic and ADF-Statistic of within dimension show significant value, and (ii) Group PP-statistics and ADF-Statistic of between dimension show significant values, which indicate null hypothesis rejected, and there is a cointegrated relationship exist in the estimated equation.

Table 12: Pedroni residual cointegration test (combined model)

Alternative hypothesis: common AR coefs. (within-dimension)		
Tests	**Statistic**	**Weighted Statistic**
v-Statistic	0.5757	-1.0028
rho-Statistic	1.7054	2.4776
PP-Statistic	-3.3448***	-0.9843
ADF-Statistic	-3.1080***	-1.0402
Alternative hypothesis: individual AR coefficient (between-dimension)		
Group rho-Statistic	3.7760	
Group PP-Statistic	-3.4890***	
Group ADF-Statistic	-2.1790***	

Source: Author's experiment (2022)

Following the same strategy of the biofuel production and consumption model, I also conduct the Kao Residual Cointegration Test to show the robustness of the panel cointegration test of the consumption model. Table 13 presents the output of the *Kao Residual Cointegration Test*. Here, the null hypothesis is there is no cointegration. According to the ADF statistics, the t-statistics is significant (-2.4415***), which supports rejecting the null hypothesis. Therefore, the *Kao Residual Cointegration Test* shows the variables are cointegrated.

Table 13: Kao cointegration test (combined model)

Statistics	**t-Statistic**
ADF	-2.4415***

Source: Author's experiment (2022)

4.4.2. Cointegrated regressions (combined model)

After the unit root and panel cointegration tests, I find a cointegration relationship in the estimated model. That is why I follow the cointegrated panel regression methods. Table 14 shows the regression output of both FMOLS. This model is used widely to experiment with regression when cointegrated relationships exist. According to Table 14, capital formation is positively significant on GDP at a 99% confidence interval level. This positive output of capital formation means that a 1% increase in the capital formation increases GDP by 0.3834%. Labour shows moderate positive significant output on economic growth at a 99% confidence interval level (coefficient is 0.3939). The output of variable, labour, indicates that a 1% increase in labour increases GDP by 0.3939%. Financial development is also significant in combined model. The coefficient is 0.0604, which is significant at 99% confidence intervals.

The most important variables in this model are the effect of biofuel production and consumption on economic expansion. Biofuel production is also very significant in FMOLS model. A 1% growth in biofuel production surge in 0.0181% GDP growth in EU. This study output indicates that a 1% rise in biofuel energy production raises GDP by 0.0181%. Considering the impact of the consumption of biofuels on economic growth, biofuel consumption is insignificant on GDP in combined model.

Table 14: Panel Fully Modified Least Squares (FMOLS) (combined model)

Variables	**FMOLS**
LnCAPITAL	0.3834***
	(0.0304)
LnLABOUR	0.3939***
	(0.1146)
LnFINDEV	0.0604***
	(0.0199)
LnBIOFPRO	0.0181***
	(0.0052)
LnBIOFCON	0.0004
	(0.0045)
R-squared	99%
Adjusted R-squared	0.9987
S.E. of regression	0.0325
Durbin-Watson stat	0.3375
Mean dependent var	6.5967
S.D. dependent var	0.9095
Sum squared residual	0.1764
Long-run variance	0.0016

Source: Author’s experiment (2022)

This study tests another experiment for the combined model that investigates the impact of both biofuel production and consumption on EU economic growth. The output of another well-known cointegrated regression, DOLS model, is mentioned here in Table 15.

Table 15: DOLS model (combined model)

Variables	DOLS
LnCAPITAL	0.3612***
	(0.0346)
LnLABOUR	0.4640***
	(0.1207)
LnFINDEV	0.0580***
	(0.0223)
LnBIOFPRO	0.0184***
	(0.0058)
LnBIOFCON	0.0007
	(0.0052)
R-squared	99%
Adjusted R-squared	0.9987
S.E. of regression	0.0326
Mean dependent var	6.5865
S.D. dependent var	0.9109
Sum squared residual	0.1892

Source: Author's experiment (2022)

According to Table 15, it can be seen that a 1% growth in biofuel production surge in 0.0184% GDP growth. Reflecting the impact of the consumption of biofuels on economic growth, biofuel consumption is also insignificant in DOLS model. I am not surprised to see this output because biofuel consumption was also insignificant in FMOLS model. The conclusion is regarding combined production and consumption in a single model, the production of biofuels has a greater impact compared to the consumption of biofuels.

4.5. Panel granger causality tests

This study also experiments the panel granger causality of all the variables, GDP, capital formation, labour, biofuel production, and biofuel consumption. Table 16 presents the output of panel granger causality test, particularly the Stacked test (common coefficient), using samples from 2001 to 2019, and the number of lags is 2. Regarding the main relation of this study, GDP, financial development, biofuel production and consumption, none of the biofuels variable cause economic growth. However, economic growth and financial development significantly causes the production and consumption of biofuels.

Table 16: Panel granger causality tests

Null Hypothesis:	F-Statistic	Prob.
Capital formation > GDP	2.7972*	0.0638
GDP > Capital formation	7.2953***	0.0009
Labour > GDP	2.7642*	0.0659
GDP > Labour	9.4430***	0.0001
Biofuel production > GDP	0.7575	0.4704
GDP > Biofuel production	6.7366***	0.0015
Financial development > GDP	6.1811***	0.0026
GDP > Financial development	26.8736***	0.0000
Biofuel consumption > GDP	1.1809	0.3096
GDP > Biofuel consumption	5.2148**	0.0064
Labour > Capital formation	1.2022	0.3031
Capital formation > Labour	5.5529***	0.0046
Biofuel production > Capital formation	0.0637	0.9383
Capital formation > Biofuel production	6.7163***	0.0016
Financial development > Capital formation	2.5612*	0.0802
Capital formation > Financial development	28.7656***	0.0000
Biofuel consumption > Capital formation	1.8394	0.1621
Capital formation > Biofuel consumption	5.2643**	0.0061
Biofuel production > Labour	2.3929*	0.0945
Labour > Biofuel production	6.5600***	0.0018
Financial development > Labour	8.5492***	0.0003
Labour > Financial development	15.2531***	0.0000
Biofuel consumption > Labour	0.7295	0.4837
Labour > Biofuel consumption	4.3554**	0.0143
Financial development > Biofuel production	13.2301***	0.0000
Biofuel production > Financial development	1.0328	0.3583
Biofuel consumption > Biofuel production	8.5865***	0.0003
Biofuel production > Biofuel consumption	1.5156	0.2227
Biofuel consumption > Financial development	1.7790	0.1720

Financial development > Biofuel consumption	7.2622***	0.0009

Source: Author’s explanation (2022)

4.6. Nexus between biofuels, financial development, and economic growth

In previous experiments, this study only analysis the impact of economic proxies (capital and labour), financial development, biofuel production, and consumption on economic expansion. In this section, this study also experiments the nexus relationship between biofuels, financial development, and economic growth. The purpose of this nexus relationship is to explore the regression relationship in other perspectives. In regression 1 (Dependent variable is GDP): financial development and biofuel production significantly promote economic growth. This output supports the findings of SAIDI (2023) and WANG et al. (2021). However, biofuel consumption is insignificant here. This insignificance is consistent with the previous analysis.

In regression 2 (Dependent variable is financial development): the key finding is GDP and biofuel consumption positively promote financial development. This study implies that biofuel consumption promotes financial development through number of channels and mechanisms. For example, higher energy consumption is also indicating the industrial development, which is also usually assumed positively connected to financial development. This recommendation is also applicable for regression 3 (dependent variable is biofuel consumption). The findings from WANG et al. (2021) are similar in case of economic growth. This study suggests the implication of the findings in following way. Biofuel consumption can increase domestic credit to the private sector by stimulating investment in biofuel infrastructure, agricultural financing, technology research, and job creation, among other factors. Government incentives and policies, as well as export opportunities, can also indirectly impact credit availability.

In regression 4 where this shows financial development impact on biofuel consumption. The finding says financial development is positively significant. In this case, the output from WANG et al. (2021) supports this study output in the case of positive relation between financial development and renewable energy consumption. Output from regression 4 indicates financial development promotes the usage of biofuel consumption. This output has also support from EREN et al. (2019) that shows financial development significantly promotes the consumption of renewable energy.

In regression 3 (dependent variable is biofuel production): biofuel consumption and economic growth significantly boost the production of biofuel and overall biofuel industry. On the other hand, biofuel production is also boosting biofuel consumption (Regression 4). This output refers vice-versa relationship.

Table 17: Nexus between biofuels, financial development, and economic growth in EU

	Dependent variables			
Independent variables	**(1) LnGDP**	**(2) LnFINDEV**	**(3) LnBIOPRO**	**(4) LnBIOCON**
LnGDP		2.0861***	4.3028***	-2.4001**
		(0.2552)	(1.0287)	(1.2231)
LnFINDEV	0.2103***		-0.6417	1.5415***
	(0.0289)		(0.3695)	(0.3866)
LnBIOPRO	0.0417***	-0.0537		0.7914***
	(0.0088)	(0.0280)		(0.0821)
LnBIOCON	-0.0126	0.0829***	0.6424***	
	(0.0082)	(0.0230)	(0.0644)	

Source: Author's explanation (2022) [Regression 1 to 4: FMOLS, Here I show 99% and 95% significance, *** and ** refers 99% and 95% significant level]

4.7. Hypotheses evaluation

- Hypothesis 1: *Biofuel production has a significant positive impact on EU economic growth **(Accepted).***
- Hypothesis 2: *Biofuel consumption has a significant positive impact on EU economic growth **(Accepted).***
- Hypothesis 3: *Biofuel production has a higher significant positive impact compared to biofuel consumption on EU economic growth **(Accepted)***
- Hypothesis 4A: *Biofuel production causes financial development and EU economic growth **(Rejected).***
- Hypothesis 4B: *Biofuel consumption causes financial development and EU economic growth **(Rejected).***
- Hypothesis 5: *Biofuel production and consumption has positive impact on financial development, and vice versa **(Partially Accepted).***

5. CONCLUSION AND POLICY IMPLICATIONS

5.1. Conclusion

This study examined the economic impact of biofuel production and consumption in 11 European Union countries. It employed various non-stationary panel data models from 2001 to 2019. The findings indicate that both biofuel production and consumption have a significant impact on economic growth, with production having a stronger influence.

In a combined model, both biofuel production and consumption were examined for their impact on economic growth. Biofuel consumption was found to be insignificant, while biofuel production had a highly significant positive impact on EU economic growth. Additionally, there is a positive relationship between biofuel consumption and financial development, with financial development also significantly promoting biofuel consumption. In summary, the bio-economy plays a significant role in EU economic aspects, and financial development consistently influences economic expansion.

This study offers several noteworthy contributions to the literature. It underscores the significance of biofuels, both in production and consumption, for EU economic growth. It emphasizes the need to prioritize biofuel production to enhance consumption effectiveness. Furthermore, it extends the relevance of biofuels to other growing EU nations. Overall, this research contributes not only to EU economics but also to global biofuel studies.

5.2. Policy implications

This study underscores biofuels' potential for economic growth and sustainability. Policymakers should prioritize biofuel development for economic benefits in both rural and urban areas. Increased biofuel investment reduces fossil fuel dependence, benefiting the environment and the economy. Encouraging affordable biofuel adoption and supporting ethanol policies can stimulate global trade and capital development. Promoting advanced biofuels from non-food sources is recommended, along with favorable tax policies to incentivize the high-tech biofuels industry. In summary, sustainable energy policies are crucial for economic development.

6. NOVEL FINDINGS AND CONTRIBUTIONS

The main key purpose of this study is to show the contribution of both production and consumption of biofuels to EU economic growth. Considering the key purpose of this study, I specified five questions that ultimately connect the contribution of this study. Considering the key questions, aims, and hypotheses of this study, the novel findings and contributions are mentioned in the following section.

1. *The first novel output:* I proved it with my research that the production of biofuels has a significant positive impact on economic growth in the EU. The output implies that the increasing and higher production and development of biofuels boost economic progress in the EU. This first contribution is aligned with the first research question, objective one, as well as hypothesis 1 of the study.
2. *The second novel output:* I verified that the consumption of biofuels significantly positively impacts economic growth in the EU. The output implies that the increasing and higher consumption and usage of biofuels boost economic progress in the EU. This second contribution is aligned with the second research question, objective two, as well as hypothesis 2 of the study.
3. *The third novel output:* Based on my research work I established that there is a comparative investigation of both production and consumption of biofuels' effects on the economic aspect of the EU. Thereby, this study contributes by showing that when comparing production and consumption in individual models, the impact of biofuel production on economic growth is relatively greater than that of biofuel consumption. This third contribution is aligned with the third research question, objective three, as well as hypothesis 3 of the study.
4. *The fourth novel output:* I investigated both production and consumption variable in a single regression and based on it in this model, including both production and consumption variables, the production of biofuels significantly and positively impacts on economic growth. On the other hand, the consumption of biofuels is slightly significant on the economic expansion. Therefore, regarding the relative significance of biofuel production and consumption in an integrated model, biofuel production has a relatively more significant and higher impact on economic growth compared to the consumption of biofuels. This fourth contribution is also aligned with the third research question, objective three, as well as hypothesis 3 of the study.
5. *The fifth novel output*, based on my research work I verified that there is a causal relationship among the variables. Notably, GDP causes both the production of biofuels and the consumption of biofuels. This contribution indicates the higher the GDP, on in other words, the more GDP expansion support higher production of biofuels as well as higher consumption of biofuels. On the other hand, none of the two variables causes GDP. Indicating production of biofuels and the consumption of biofuels do not cause EU GDP.
6. *The sixth novel output*, I verified that biofuel consumption has positively significant impact on financial development. On the other hand, financial development also positively impacts on biofuel consumption.

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LIST OF PUBLICATIONS

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List of publications related to the dissertation

<u>Articles, studies</u> (3)

1. **Hasan, M. M.**, Abedin, M. Z., Amin, M. B., Nekmahmud, M., Oláh, J.: Sustainable biofuel economy: A mapping through bibliometric research.
   Journal of Environmental Management. 336, 1-17, 2023. ISSN: 0301-4797.
   DOI: http://dx.doi.org/10.1016/j.jenvman.2023.117644
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2. **Hasan, M. M.**: Energy economic expansion with production and consumption in BRICS countries.
   Energy Strategy Reviews. 44, 1-12, 2022. ISSN: 2211-467X.
   DOI: http://dx.doi.org/10.1016/j.esr.2022.101005
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3. **Hasan, M. M.**, Oláh, J.: Present landscape of biofuel production and consumption in European Union.
   Journal of Central European Green Innovation. 10 (2), 37-50, 2022. EISSN: 2064-3004.
   DOI: http://dx.doi.org/10.33038/jcegi.3472

<u>Conference presentations</u> (1)

4. **Hasan, M. M.**, Amin, M. B., Nekmahmud, M.: Mapping the potential of a sustainable biofuel economy through bibliometric research.
   In: European Union Policies International Thematic Conference : Book of Abstracts. Ed.: Kiss Rebeka, Doktoranduszok Országos Szövetsége, Budapest, 20, 2022. ISBN: 9786156457080

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List of other publications

Articles, studies (7)

5. Khaing Soe, A., Gavurova, B., Oláh, J., **Hasan, M. M.**: Does auditor's attributes impact on professional judgement in financial audit?: empirical evidence from Myanmar Sai.
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6. He, K., Oláh, J., **Hasan, M. M.**: The influence of psychological ownership and social support on organizational resilience: the mediating role of organizational identity.
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8. Rabbi, M. F., **Hasan, M. M.**, Kovács, S.: Food Security and Transition towards Sustainability.
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9. Oláh, J., Hidayat, Y. A., Dacko-Pikiewicz, Z., **Hasan, M. M.**, Popp, J.: Inter-Organizational Trust on Financial Performance: Proposing Innovation as a Mediating Variable to Sustain in a Disruptive Era.
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11. **Hasan, M. M.**, Popp, J., Oláh, J.: Current landscape and influence of big data on finance. *Journal of Big Data. 7* (21), 1-17, 2020. EISSN: 2196-1115.
DOI: http://dx.doi.org/10.1186/s40537-020-00291-z

Total IF of journals (all publications): 34,605
Total IF of journals (publications related to the dissertation): 18,92

The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on the basis of the Journal Citation Report (Impact Factor) database.

19 June, 2023

FUNDING ACKNOWLEDGEMENT

Project no. 132805 has been implemented with the support provided from the National Research, Development and Innovation Fund of Hungary, financed under the K_19 funding scheme.