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The Effects of Using Bioenergy: Is It All Good?

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Abstract

This paper will examine the economic, social, and environmental effects of bioenergy using the Ordinary Least Square Method (OLS) and the Fully-Modified Ordinary Least Square Method (FM-OLS) in Brazil, Austria, and Turkey, for 2001-2016. We formed two different equations; the first one aims to see how bioenergy usage, deforestation, and GDP growth rate affect CO_2 emission, affecting both the environment and society. We use the second equation for investigating the economic effects of bioenergy, together with the other energy resources. We expect highly significant relationships between the variables; however, the outcome is not relevant to our expectations. Although some of the variables are significant and effective, there is no absolute relationship between the variables. The outcome depends on the different dynamics of the countries, and the Model is open to the outside factors.

Keywords: ols, fmols, biomass energy, deforestation, CO_2 emission, gdp growth rate

1. Introduction

Energy is one of the main driving forces of the countries; it is used widely from small households to large industrial activities. Therefore, the availability and sustainability of energy resources become an important issue. Although the share of conventional energy resources, such as natural gas, oil, or coal, in the energy supply is still high, renewable energy resources are also increasing. Figure 1 shows the world's total energy supply (kilotonnes of oil equivalent, ktoe) and renewable energy resources as a percentage of the total energy supply for 2000-2018, which has an increasing trend, especially for the last ten years.

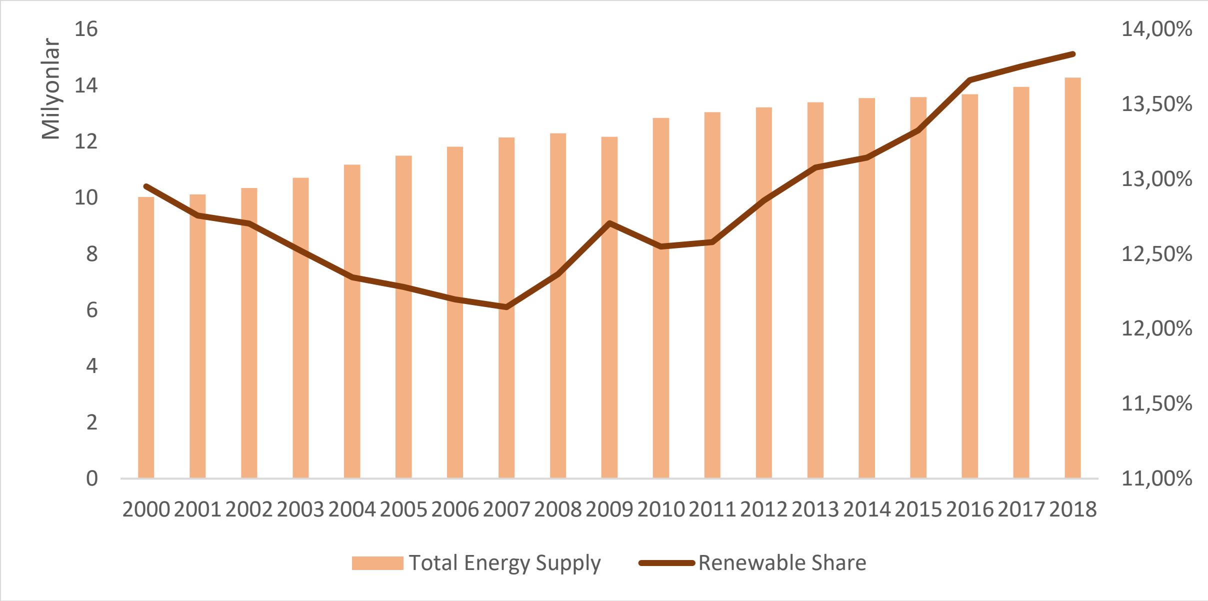

Figure 1. Total Energy Supply and Renewable Share IEA, World Energy Balances Highlights, 2020

Since there are different types of renewable energy, it is important to analyze these resources separately to see which one is more dominant than the others. Figure 2 shows the world's total energy supply (ktoe) from renewable energy resources (RES); Biofuels & Waste, Hydro, Wind & solar, etc., including tide, wave, and ocean energy. It is clear that the usage of biofuels & waste is much higher than the other renewable energy resources. Therefore, it is important to analyze bioenergy since it is the most widely-used renewable energy resource.

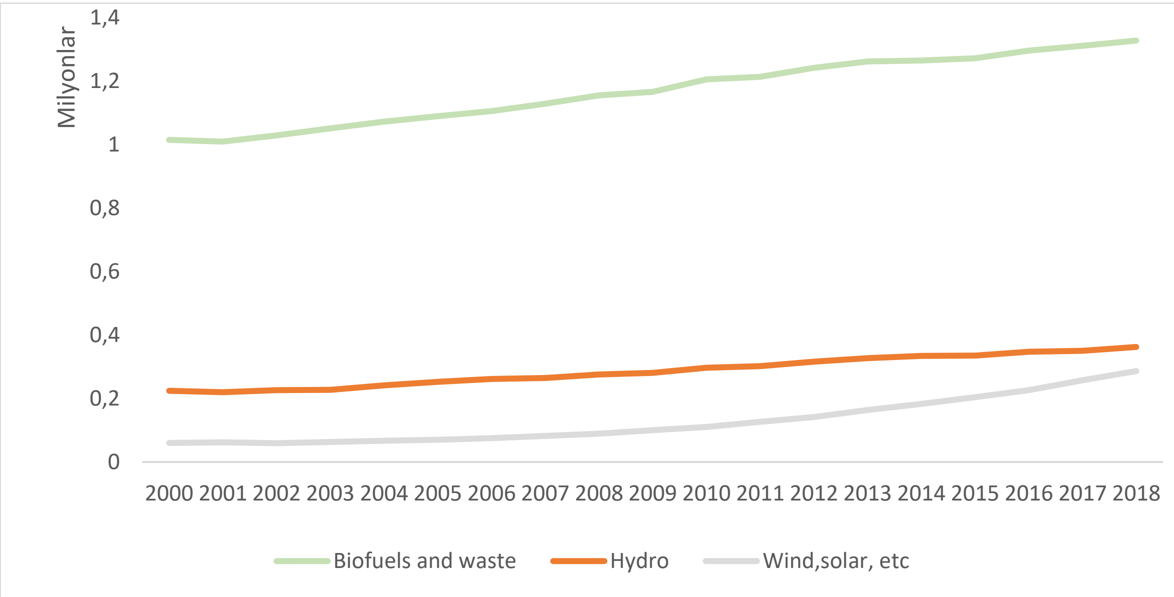

Figure 2. Total Energy Supply from RES IEA, World Energy Balances Highlights, 2020

There are several ways to categorize biomass energy depending on its main resource or how it is used. Agricultural crops and residues, forests, animal residues, or organic wastes can be biomass resources. Long et al. (2013) mentioned more generally accepted two main categories; productive biomass and unused biomass. Each category has sub-groups; "agricultural, forestry and aquatic biomass, waste biomass and planted biomass." Each of these biomass resources has a different potential for bioenergy. Bioenergy obtained from these various biomass resources can meet different demands such as electricity, heating for households and industries, and fuel.

Since biomass is such a widely-used energy resource, it can replace conventional energy resources. Therefore, it is essential to capture different aspects of this resource, such as economic, environmental, and social. The biomass's economic side mostly depends on the production cost of these resources and aims to reach a cost-efficient result. The analysis is not easy for biomass because it is multi-dimensional. Choosing the right cost-efficient biomass resource can help to meet energy demand, create job opportunities; that is, it can boost the economy. However, these economic benefits are only one part of the story. The sustainability of the biomass should also be considered since the usage of bioenergy can cause problems for agricultural lands and food stocks, water security, forests, and biodiversity. Therefore, it is essential to analyze biomass from a wide perspective. This paper aims to provide the different impacts of biomass usage globally by using econometric methods, explained in the following sections. In order to reach a complete analysis, different countries will be chosen.

The rest of the paper is organized as follows; there will be a literature review to analyze the biomass in the second section. In the third section, the methodology and data used in the study are explained, and in the following section, the main findings will be presented. The fifth section concludes the paper.

2. Literature Review

Among the renewable energy resources, bioenergy has the largest share of the total renewable energy supply (World Bioenergy Association, 2019). Also, together with its high share, bioenergy usage has increased globally, especially after the 1980s (Chum et al., 2011). There is a wide range of bioenergy usage; it can meet different needs such as heating, electricity, or fuel. Therefore, it is essential to examine the effects of bioenergy which can replace other conventional energy resources as its usage increase. Many publications related to bioenergy and its effects use different methods; however, no single conclusion is reached. Upham et al. (2009) stated that" biofuels are hotly debated today because their overall impacts, also concerning wider ecological and socioeconomic issues, are uncertain and difficult to assess." Therefore, it is impossible to limit effects into a single dimension since "bioenergy has complex societal and environmental interactions" (Chum et al., 2011). The complexity of the bioenergy cause problems while examining the effects, and it necessitates a comprehensive analysis considering both positive and negative sides of the story. Faaij (2006) stated that while bioenergy can create environmental, social and, economic conveniences, it may also have controversial effects in the same areas. Also, Koh & Ghazou (2008) pointed out the problems that can come forward while investigating the effects of bioenergy due to interlinkages between land use, ecosystem services, and food security.

Similarly, Scarlatt & Dallemand (2011) pointed out that although bioenergy has the potential of replacing fossil fuels, creating job opportunities and development, there are also uncertainties related to the complexity of biofuels. In this paper, the focus will be on these opposite effects, and there will be an effort to find whether the positive effects dominate the negatives or not. To answer this question, the appropriate method should be chosen.

There are lots of methods to investigate the effects of using bioenergy. For instance, Havlı´k et al. (2011) used a recursive dynamic partial equilibrium model to see how bioenergy affects greenhouse gas (GHG) emissions by combining biophysical and technological data. Buongiorno et al. (2011) used "a spatial dynamic model to analyze how increasing bioenergy usage affects the global forest sector." Another partial equilibrium model that brings producer and consumer surplus together was used to analyze the effects of the expansion of bioenergy by Bryngelsson & Lindgren (2013). In addition, Madlener & Koller (2007) examined the effects of the policies aim increasing biomass usage in Austria by using a static input-output (I-O) analysis. Bilgili et al. (2017) used a different method than the mentioned ones, the asymmetric causality test, and aimed to search the relationship between bioenergy, CO_2 emission, and GDP in the USA. Unlike these models, Dale, V. H. et al. (2013) focused on the socioeconomic side of bioenergy, and she chose several indicators for their analysis that are easy to measure depending on social welfare, energy security, acceptance, and trade. Also, Upreti, B. R. (2004) focused on the disagreement related to bioenergy deployment in England and Wales and used interviews, surveys, focus group discussions, and document research. In addition to these models, Öztürk & Bilgili (2015) followed an econometric path to see whether there is a relationship between economic growth and biomass consumption; they used a dynamic panel analysis of Sub-Sahara African countries; also, they followed a similar pattern for the G7 countries as well. Sulaiman et al. (2020) analyzed the effect of wood biomass energy consumption on CO_2 emissions in 27 European Union (EU) member countries for 1990-2017 by comparing the results from OLS, DOLS, and FM-OLS models. Similar research was conducted by Ali et al. (2018) to investigate the relationship between economic growth and biomass energy consumption in ASEAN economic union member countries: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, and Singapore, Thailand, and Vietnam. They (2018) used dynamic OLS, fully modified OLS, and panel OLS. Regression analyses are especially useful for investigating the economic effects of bioenergy.

The diversity of methods for analyzing bioenergy coincides with the complexity of bioenergy. It is important to develop a model to capture the overall picture since bioenergy can become the world's next alternative energy resource. Therefore, the focus of this paper will not be on a single topic. Instead, there will be a combination of the variables such as total energy supply, carbon emission, deforestation, and waste usage, which are affected by bioenergy. Following an econometric model will be more suitable for this paper since the aim is to see how each variable is affected by using biomass to meet energy demand.

Two countries, Brazil and Austria, are chosen for analysis. Both of these countries are in the countries supplying bioenergy the most. (IEA, 2020) We want to compare one developing and one developed country. The obvious choice for the developing country is Brazil, with its high supply of bioenergy. The bioenergy supply of the developed countries does not vary too much. Therefore, the choice is made randomly, and the result is Austria. According to the World Bank Country Groups by income, Austria is a high-income country, whereas Brazil is an upper-middle-income country. In addition to these countries, the analysis is made for Turkey to see Turkey's position in biomass usage. We expect that although using biomass is beneficial to the total energy supply, its adverse effects will be higher when economic, natural, and social factors are considered. The method and data will be explained in more detail in the next section.

3. Methodology and Data

This paper will develop different econometric equations with related data of the chosen countries and see the economics, social and natural effects of biomass energy consumption. These data are the total energy supply from different types of energy resources, (oil, coal, natural gas, hydro, biofuels and waste, solar & wind, etc.), the level of total CO_2 emission, GDP growth, and deforestation rate for energy production for each country for 2001-2016.

The total energy supply of different energy resources is obtained from the World Energy Balances, IEA (2020). The biofuels and waste data include all types of bioenergy, such as wood, industrial waste, municipal waste, and biogases. It is measured by the kilotons of oil equivalent, ktoe.

CO_2 emission, GDP growth rate is obtained from the World Bank Development Indicators. CO_2 emission includes the emission from burning fossil fuels and the manufacture of cement, together with "carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring" (World Bank), and it is measured with kilometric tons.

"GDP growth rate is the annual percentage growth rate of GDP at market prices based on constant local currency" (World Bank), and it is based on constant 2010 US$. The deforestation rate is measured by kilo/hectares, and it includes tree cover losses; it is obtained from the dataset of Global Forest Watch. The data set covered Brazil, Austria, and Turkey in 2001-2016. Although, the nuclear energy supply is available for Brazil, it is not used to produce energy in Austria and Turkey. Therefore, it is excluded for this analysis.

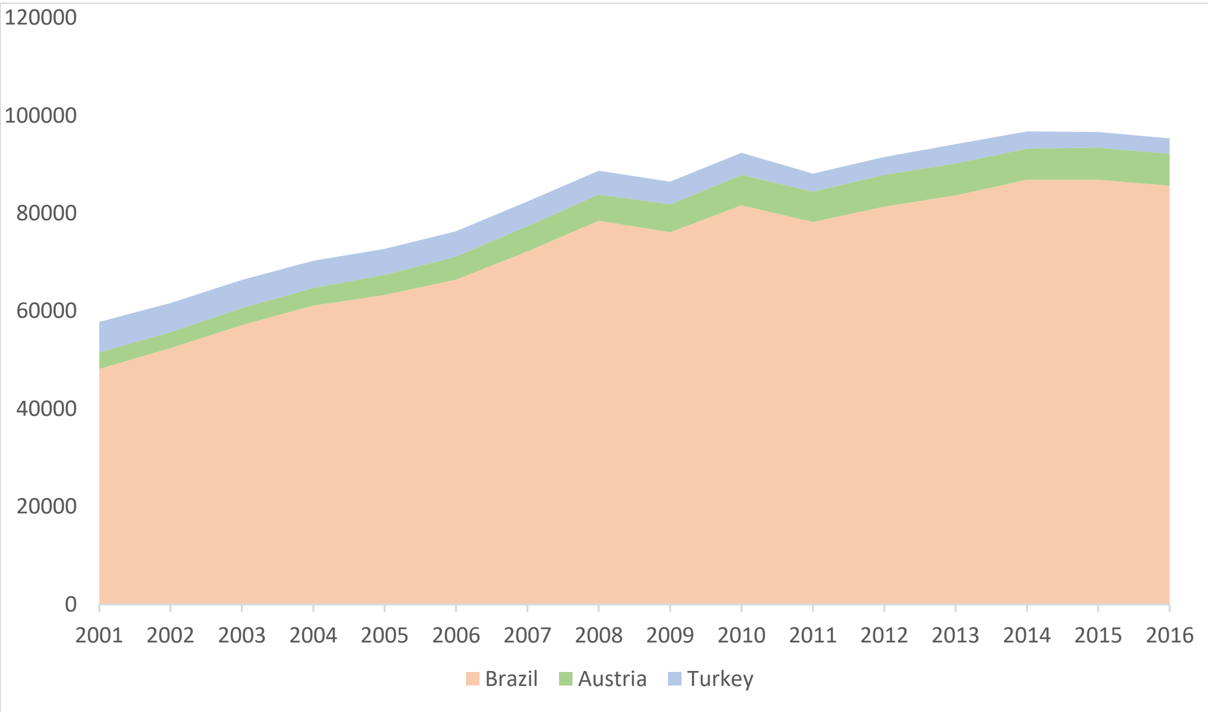

Figure 3. Total Energy Supply from Biofuels and Waste (ktoe)

Figure 3 shows the chosen countries' total energy supply from biofuels and waste. Brazil has the highest energy supply from biofuels and waste. Austria and Turkey fell behind Brazil. They have very similar supply levels.

To analyze the relationship between the data by using ordinary least square (OLS) and fully modified ordinary least square (FM-OLS) methods. The two methods are used together because the OLS method may lead to a critical endogeneity and similarity problem (Bilgili & Ozturk, 2015). Philips and Hansen formed the FM-OLS model in 1990 to present the best estimates for cointegrated regressions (Philips, 1993). FM-OLS is used for "modifying the least square to account for serial correlation effects and for the endogeneity in the regressors that results from the existence of a cointegrating relationship," according to Philips (1993). For this paper, we choose to use the FM-OLS model since, with robustness check, the results obtained from FM-OLS will be the same and significant. (Suleiman et al.,2020)

The use of OLS and FM-OLS follows these steps; firstly, the unit root test is used to see whether there is an autocorrelation problem. We use the Dickey-Fuller test, and the data is not correlated for the OLS models. Also, the results are improved with the FM-OLS models.

Secondly, the following models are formed.

$$CO_{2\,kt} = u_0 + u_1\, BS_{kt} + u_2\, GDPG_{kt} + u_3 DF_{kt} + \delta_{kt} \quad (1)$$

We develop Model (1), where $CO_{2\,kt}$ is the CO_2 emission for country k in t time, BS_{kt} refers to the total biofuels and waste supply for country k in t time, $GDPG_{kt}$ represents GDP growth rate (annual, %). DF_{kt} is the deforestation rate for country k in t time. Model (1) aims to measure the environmental and societal effects of bioenergy, together with the other related variables.

$$GDPG_{kt} = u_0 + u_1BS_{kt} + u_2COAL_{kt} + u_3HYDRO_{kt} + u_4NATURALGAS_{kt} + u_5OIL_{kt} + u_6OTHERRENEWABLES_{kt} + \delta_{kt} \quad (2)$$

We also develop Model (2), where $GDPG_{kt}$ is the GDP growth rate (annual, %) for country k in t time, BS_{kt} is the level of the total biofuels and waste supply for country k in t time, $COAL_{kt}$ refers to the level of the total coal supply for country k in t time, $HYDRO_{kt}$ represents the level of total energy supply from hydropower for country k in t time, $NATURALGAS_{kt}$ and OIL_{kt} refer to the level of energy supply from the natural gas and oil for country k in t time, and $OTHERRENEWABLES_{kt}$ is the level of the total renewable energy sources such as wind, solar, geothermal, etc. for country k in t time. Model (2) aims to show how the total supply of biomass affects the GDP growth rate, an economic indicator, with other energy resources for different countries at different times.

4. Findings

The first country observed will be Brazil for 2001-2016. Brazil is one of the top countries that meet its energy demand with biofuels and waste. Therefore, it is important to analyze the effects of this high level of high usage. Following two regressions are going to be used for the analysis;

$$CO_{2\,kt} = u_0 + u_1 BS_{kt} + u_2 GDPG_{kt} + u_3DF_{kt} + \delta_{kt} \quad (1)$$

The first equation will show the environmental (and also social effects) of using biomass energy. The results are;

Variable	Coefficient	Std. Error	t-Statistic	Prob.
BS	4.371701	0.664409	6.579834	0.0000
GDPG	-4022.329	2705.601	-1.486668	0.1629
DF	1.43E-12	6.89E-13	2.069554	0.0607
C	78780.79	50328.74	1.565324	0.1435

R-squared	0.845364	Mean dependent var	404700.4
Adjusted R-squared	0.806705	S.D. dependent var	71397.07
S.E. of regression	31389.99	Akaike info criterion	23.75868
Sum squared resid	1.18E+10	Schwarz criterion	23.95183
Log likelihood	-186.0695	Hannan-Quinn criter.	23.76857
F-statistic	21.86714	Durbin-Watson stat	1.242659
Prob(F-statistic)	0.000037		

Table 1. OLS for Brazil

NOTE: Before analyzing the results, it is important to note the significance level for the regressions is equal to 0.05.

Table 1 shows the OLS results for Brazil. It includes the intercept term and the independent variables in the regression. First, the statistical significance of the independent variables should be checked. It is obvious that whereas biomass supply is statistically significant, the others are not. They are not contributing to explain the dependent variable, CO_2 emission. Also, it is important to note that the probability level of the deforestation rate is just slightly higher than the Model's significance level. The coefficient of the biomass supply is positive; that is, as the more energy from biomass is supplied, the more carbon emission increases. It coincides with our idea that using biomass for meeting energy demand has adverse environmental effects, which may widen in the future. The Model's adjusted R^2 shows that the Model is good enough to explain the dependent variable, which is not surprising since the F-statistics show that the Model is jointly significant. However, relying solely on the OLS model is not enough. Therefore, the following FM-OLS model is constructed as well.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
BS	3.574706	1.024057	3.490730	0.0051
GDPG	-6022.201	3323.589	-1.811957	0.0974
DF	2.08E-12	9.29E-13	2.237911	0.0469
C	136157.7	75897.96	1.793957	0.1003
R-squared	0.804725	Mean dependent var		409184.9
Adjusted R-squared	0.751469	S.D. dependent var		71532.53
S.E. of regression	35661.04	Sum squared resid		1.40E+10
Long-run variance	1.40E+09			

Table 2. FM-OLS Results for Brazil

FM-OLS analysis for Brazil gives us a better understanding of the individual effects of the independent variables. Following the same procedure as before, table 2 shows that the biomass supply is significant and has a positive coefficient, same as the OLS analysis. GDP growth is insignificant; it is not an expected result since we expect to have a positive relationship between GDP growth and CO_2 emission however; Brazil's GDP rate did not follow a consistent path. The GDP growth rates fell into the negative levels between 2014-2016 due to the economic crisis. Vartanian and de Souza Garbe (2019) stated that" between 2014 and 2016, the Brazilian economy faced one of the worst recessions in history." Therefore, we cannot expect to have a normal relationship between GDP growth and CO_2 emission. The most important difference from the OLS is that the deforestation rate is significant at the FM-OLS model, and it has a positive coefficient. It means that the increase in the deforestation rate will also increase the emission levels. According to the IEA (2020), primary solid biofuels, provided directly from the forests and agriculture, are highly used to produce energy, especially electricity. This causes an increase in the deforestation rate; when combined with high biomass usage, the CO_2 emission increases, affecting society. Although the adjusted R^2 from FM-OLS is not high as in the OLS model, it is still high enough to explain the Model.

We will repeat the same processes for Austria. Although its total energy supply from biofuels and waste is not high as Brazil's, it still has a significant level of biomass supply. Table 3 shows the OLS results for Austria.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDPG	1039.195	476.7669	2.179671	0.0499
BS	-2.244312	0.636020	-3.528681	0.0042
DF	-1.91E-14	9.29E-14	-0.205790	0.8404
C	79346.74	3665.114	21.64919	0.0000

R-squared	0.646720	Mean dependent var	68868.13
Adjusted R-squared	0.558401	S.D. dependent var	4665.452
S.E. of regression	3100.330	Akaike info criterion	19.12872
Sum squared resid	1.15E+08	Schwarz criterion	19.32187
Log likelihood	-149.0298	Hannan-Quinn criter.	19.13861
F-statistic	7.322479	Durbin-Watson stat	0.753005
Prob(F-statistic)	0.004758		

Table 3. OLS results for Austria

From table 3, it is seen that the Biomass Supply and GDP growth are significant in the Model. GDP growth has a positive coefficient, as expected. However, the biomass supply has a negative coefficient, as opposed to the results of Brazil. Also, the deforestation rate is insignificant in the OLS model. Adjusted R^2 of the Model shows that the Model is insufficient to explain relationships we wish to get, although the Model is jointly significant according to the F-statistics. Therefore, the FM-OLS model is once again necessary.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDPG	1067.713	348.4593	3.064096	0.0108
BS	-2.604047	0.501641	-5.191056	0.0003
DF	-1.82E-14	6.78E-14	-0.267762	0.7938
C	80582.73	2968.911	27.14219	0.0000

R-squared	0.697650	Mean dependent var	68932.00
Adjusted R-squared	0.615191	S.D. dependent var	4821.955
S.E. of regression	2991.202	Sum squared resid	98420214
Long-run variance	5072979.		

Table 4. FM-OLS results for Austria

First of all, it is important to note that, with FM-OLS, the adjusted R^2 of the Model improved; that is, the Model becomes better at explaining the relationship between the variables. Biomass supply and GDP growth are again significant for this Model, whereas deforestation is not. Although the overall Model is improved, the insignificance of these variables should be analyzed. First of all, the one reason why we cannot get the result we expected is that the CO_2 emission has a decreasing trend in Austria, as opposed to Brazil. Also, World Energy Balances, IEA (2020) shows that Austria's total energy supply from conventional energy resources, especially coal, and natural gas follows a decreasing trend. Therefore, it is hard to capture the relationship between CO_2 emission and biomass supply, although its share increases. Similarly, deforestation rates are decline significantly in Austria in recent years.

Lastly, the same methods will be repeated to analyze Turkey. Turkey does not have high levels of energy supply from biofuels and waste. However, it has a similar amount as Austria. The OLS and FM-OLS results for Turkey will be analyzed together because there are no stand-out differences.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
BS	-55.93303	3.134574	-17.84390	0.0000
GDPG	-366.9011	548.9117	-0.668416	0.5165
DF	3.54E-13	3.02E-13	1.174122	0.2631
C	539379.8	13390.69	40.28022	0.0000

R-squared	0.974868	Mean dependent var	283246.6
Adjusted R-squared	0.968585	S.D. dependent var	55235.25
S.E. of regression	9790.015	Akaike info criterion	21.42843
Sum squared resid	1.15E+09	Schwarz criterion	21.62158
Log likelihood	-167.4275	Hannan-Quinn criter.	21.43832
F-statistic	155.1608	Durbin-Watson stat	1.871641
Prob(F-statistic)	0.000000		

Table 5. OLS results for Turkey

Variable	Coefficient	Std. Error	t-Statistic	Prob.
BS	-52.92624	2.542964	-20.81282	0.0000
GDPG	-770.1153	506.7692	-1.519657	0.1568
DF	2.28E-13	2.27E-13	1.006566	0.3358
C	530200.8	10119.66	52.39313	0.0000

R-squared	0.969760	Mean dependent var	289158.6
Adjusted R-squared	0.961513	S.D. dependent var	51669.08
S.E. of regression	10136.56	Sum squared resid	1.13E+09
Long-run variance	52392586		

Table 6. FM-OLS results for Turkey

According to both tables, the Model seems good enough to explain relationships based on their adjusted R^2 values. However, the independent variables are insignificant in both models; GDP growth and deforestation rate. At the same time, the biomass supply is significant and has a negative coefficient. Similar to Austria, this result is not expected. When the GDP growth rate of Turkey is analyzed, it is seen that there is no consistent trend. There are fluctuations, which may harm the relationship between CO_2 emission and GDP growth. Also, the CO_2 emission in Turkey has an increasing trend as opposed to Austria. Increasing emissions of Turkey and Brazil can be explained by the fact that these are not developed countries and maybe fell behind shifting to cleaner energy resources. Also, as opposed to Austria and Brazil, the total energy supply from biofuels and waste is decreasing in Turkey. Therefore, it is hard to obtain a significant relationship. In addition, the shares of conventional energy resources, coal, oil, and natural gas, in total supply are significantly higher than the other two countries. Therefore, analyzing the effects of using biomass solely is not easy to capture.

In order to measure the economic effects of the bioenergy, Model (2) will be used. We wish to see how bioenergy supply stands out between the other energy resources and how it contributes to the economic growth of the countries. The significance level of the regressions is 0.05.

$$GDPG_{kt} = u_0 + u_1BS_{kt} + u_2COAL_{kt} + u_3HYDRO_{kt} + u_4NATURALGAS_{kt} + u_5OIL_{kt} + u_6OTHERRENEWABLES_{kt} + \delta_{kt} \quad (2)$$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
BS	0.000260	0.000257	1.011012	0.3384
COAL	0.001767	0.000881	2.006753	0.0757
HYDRO	6.79E-05	0.000431	0.157593	0.8783
NATURALGAS	-0.000462	0.000460	-1.004628	0.3413
OIL	-9.23E-05	0.000126	-0.734547	0.4813
OTHERRENEWABLES	-0.003116	0.000868	-3.591195	0.0058
C	-21.68659	14.13077	-1.534707	0.1592

R-squared	0.768854	Mean dependent var	2.478591
Adjusted R-squared	0.614756	S.D. dependent var	3.108577
S.E. of regression	1.929432	Akaike info criterion	4.451965
Sum squared resid	33.50439	Schwarz criterion	4.789972
Log likelihood	-28.61572	Hannan-Quinn criter.	4.469273
F-statistic	4.989392	Durbin-Watson stat	3.108284
Prob(F-statistic)	0.016161		

Table 7. OLS Estimation for Brazil

Table 7 shows the results of OLS estimation for Brazil. When we check the significance of the independent variables based on their p-values, it can be observed that other renewable energy sources have significant p-value; however, the coefficient of the different renewable energy sources is negative, which means that less usage of these resources will increase the GDP growth rate of Brazil. This can result from the fact that the energy supply obtained from conventional energy resources is much higher than the renewable energy resources. Therefore, it is hard to obtain a direct relationship. The total energy supply from biofuels and waste seems insignificant, which is opposite to our expectation since the energy supply from biofuels and waste is very high in Brazil. Therefore, the OLS estimation model is not good enough to see better results, so we also use the FMOLS model.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
BS	0.000281	0.000120	2.340101	0.0474
COAL	0.001927	0.000407	4.736465	0.0015
HYDRO	2.54E-05	0.000222	0.114346	0.9118
NATURALGAS	-0.000532	0.000255	-2.088163	0.0702
OIL	-8.73E-05	7.87E-05	-1.109449	0.2995
OTHERRENEWABLES	-0.003016	0.000392	-7.694810	0.0001
C	-23.19590	6.966047	-3.329851	0.0104

R-squared	0.768464	Mean dependent var	2.551170
Adjusted R-squared	0.594812	S.D. dependent var	3.203619
S.E. of regression	2.039243	Sum squared resid	33.26809
Long-run variance	0.731226		

Table 8. FM-OLS Estimation for Brazil

After using the FM-OLS model, it can be seen that the level of total biomass supply and the level of total coal supply become significant based on their p-values which are less than the value 0.05. Moreover, their coefficients are positive, which means the dependent variable, the biomass supply, and the coal supply move together, contributing to the GDP growth. Although these variables became more significant, they may improve the Model by less than expected because the adjusted R-squared decreased compared to the OLS model.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
BS	-7.78E-05	0.000805	-0.096661	0.9251
COAL	0.006330	0.001952	3.243306	0.0101
HYDRO	-0.000432	0.001796	-0.240467	0.8154
NATURALGAS	0.000461	0.001188	0.388100	0.7070
OIL	-0.001030	0.001040	-0.990273	0.3479
OTHERRENEWABLES	0.005460	0.004088	1.335705	0.2144
C	-11.84643	14.62726	-0.809887	0.4389
R-squared	0.684827	Mean dependent var		1.427983
Adjusted R-squared	0.474711	S.D. dependent var		1.732914
S.E. of regression	1.255960	Akaike info criterion		3.593314
Sum squared resid	14.19693	Schwarz criterion		3.931322
Log likelihood	-21.74651	Hannan-Quinn criter.		3.610623
F-statistic	3.259287	Durbin-Watson stat		2.554683
Prob(F-statistic)	0.054761			

Table 9. OLS Estimation for Austria

Table 9. shows that the results of OLS estimation for Austria and all independent variables are insignificant except the level of total coal supply based on their p-values. Therefore, we use the FM-OLS model to make the Model (2) better.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
BS	-0.000262	0.000478	-0.548062	0.5986
COAL	0.006348	0.001086	5.847096	0.0004
HYDRO	-0.000547	0.001002	-0.546468	0.5996
NATURALGAS	0.000448	0.000657	0.681936	0.5145
OIL	-0.001123	0.000626	-1.794180	0.1105
OTHERRENEWABLES	0.006525	0.002259	2.887783	0.0203
C	-9.668646	8.578055	-1.127137	0.2924
R-squared	0.682052	Mean dependent var		1.438704
Adjusted R-squared	0.443590	S.D. dependent var		1.793187
S.E. of regression	1.337589	Sum squared resid		14.31316
Long-run variance	0.480384			

Table 10. FMOLS Estimation for Austria

According to Table 10. the level of total coal supply and the level of other renewables supply such as solar, wind, etc. became more significant to explain the dependent variable, and their coefficients are positive, which means there is a positive relationship between the GDP growth rate and the total supply of other renewables energy & total coal supply. According to IEA, Austria imported 97% of its total consumption of coal in 2016. It can be considered as Austria imports raw material and then turns out high valuable consumption tools such as electricity or liquid fuel with high quality. However, the level of total biomass supply is insignificant in contrast to what we expect. Also, the adjusted R-squared decreased in the FM-OLS model.

The OLS and FM-OLS tables for Turkey are given below together;

Variable	Coefficient	Std. Error	t-Statistic	Prob.
BS	-0.003067	0.009212	-0.332903	0.7468
COAL	-0.001225	0.000790	-1.550624	0.1554
HYDRO	0.003896	0.002732	1.426373	0.1875
NATURALGAS	0.000476	0.000653	0.728782	0.4847
OIL	0.000697	0.001736	0.401385	0.6975
OTHERRENEWABLES	-0.002624	0.003158	-0.831179	0.4274
C	10.85903	58.28273	0.186316	0.8563
R-squared	0.598203	Mean dependent var		5.030084
Adjusted R-squared	0.330339	S.D. dependent var		4.770359
S.E. of regression	3.903719	Akaike info criterion		5.861372
Sum squared resid	137.1512	Schwarz criterion		6.199380
Log likelihood	-39.89098	Hannan-Quinn criter.		5.878681
F-statistic	2.233232	Durbin-Watson stat		2.145211
Prob(F-statistic)	0.134153			

Table 11. OLS Estimation for Turkey

Variable	Coefficient	Std. Error	t-Statistic	Prob.
BS	-0.005266	0.004521	-1.164707	0.2777
COAL	-0.001485	0.000391	-3.801226	0.0052
HYDRO	0.003409	0.001394	2.445974	0.0402
NATURALGAS	0.000374	0.000321	1.165241	0.2775
OIL	0.001043	0.000853	1.222750	0.2562
OTHERRENEWABLES	-0.003009	0.001551	-1.939811	0.0884
C	23.47443	28.67985	0.818499	0.4368
R-squared	0.540368	Mean dependent var		5.748756
Adjusted R-squared	0.195644	S.D. dependent var		3.940514
S.E. of regression	3.534085	Sum squared resid		99.91808
Long-run variance	3.665330			

Table 12. FM-OLS Estimation for Turkey

The estimation results of OLS and FM-OLS models for Turkey are nearly identical as Austria except for the coefficients of total other renewable energy supply and the total supply of coal, which are negative for Turkey, and there is a reverse relationship between the GDP growth rate and using renewable energy & coal supply. The high amount of government subsidies and incorrect conditions and tools about giving subsidies may cause this reverse relationship, especially in renewable energy. Also, the share of renewable energy in Turkey is low. Therefore, it is hard to get consistent results.

5. Conclusion

In this paper, we investigate the social, environmental, and economic effects of using bioenergy. Two countries are chosen for analysis; Brazil and Austria, one developing and one developed country. In addition to these, Turkey is added to see our country's position in bioenergy. Although bioenergy is the most used renewable energy resource in the world, it comes with side effects. We expected to see these side effects dominate the benefits of using bioenergy. CO_2 emission is chosen as an indicator for environmental and social effects because CO_2 emission causes problems such as climate change and global warming. Also, these environmental changes may cause natural disasters, such as flood, and drought, which also causes social problems. People's health can be affected badly, causing work-day losses. For analyzing the economic effects, the GDP growth rate is chosen since it shows the improvement of the countries. GDP growth is regressed together with different energy resources since we wish to see how bioenergy supply behaves. Another important variable is the deforestation rate, used as an independent variable. The deforestation rate shows the losses of the forests, which can be caused by construction and other industrial activities. However, it is also a resource for bioenergy. Therefore, it is added to the analysis. All of these variables are used with the total energy supply from biofuels and waste. To analyze these variables, OLS and FMOLS are used together. Although OLS models are useful for estimating similar work, FMOLS is also added because it eliminates the similarity bias in the OLS regression caused by the correlation.

Before conducting the models, we expected to see that there will be a direct and clear relationship between variables, and the negative effects will dominate the others. However, the regression from OLS and FMOLS show that there is no single strong relationship. The results highly depend on the dynamics of the countries. For Austria and Turkey, there is no significant relationship between CO_2 emission and bioenergy supply. Similarly, the Model cannot capture a relationship between economic growth and bioenergy supply. However, the bioenergy supply is significant for both models in Brazil. Therefore, we can see partially that the negative effects dominate the positive ones. The differences of the countries cause these differences in the results. Bioenergy is a highly dominant energy resource in Brazil; therefore, the effects are clearer here than the others.

On the other hand, the bioenergy supply is not as high for Austria and Turkey as in Brazil. Conventional energy resources have an important share for these countries, especially for Turkey. Therefore, the special effect of bioenergy is not easy to capture. Also, the policy implications of the countries can be effective. For example, Brazil has one of the biggest bioenergy resources; the Amazon Forests. Since they can easily reach these resources, it is not costly to use it for energy supply, which increases the level of deforestation and CO_2 emission, increasing the negative effects of using bioenergy, as we expected. However, there is no such case for Austria and Turkey. As mentioned before, there is a high portion of coal import in Austria, increasing the CO_2 emission. Similarly, in Turkey, energy resources like coal and natural gas are highly dominant, and there is an effort to increase nuclear energy. Therefore, bioenergy is left behind in these countries, making our Model insignificant as opposed to Brazil.

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