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## Article

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## How Accurate is it to Define Biofuels as Renewable Energy? A Theoretical and Empirical Analysis

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### ABSTRACT

Currently, energy needs are largely provided from fossil fuels. However, fossil fuels, which have a history of about 200 years, tend to run out every day. On the other hand, the human population is growing rapidly. In this context, it is of great importance that the resources to meet the energy needs of the growing population are sustainable. Energy sources that meet this definition have entered the literature as “renewable energy.” In the current literature, biofuels are defined as renewable energy sources. Yet, biofuels are fuels of biological origin that depend on agricultural production. Further biofuel production takes place at the expense of the use of land allocated for food production. The reduction of land allocated to food production can directly affect the prices of agricultural products. Therefore, interest in biofuel production has decreased. Is it right to accept biofuels as renewable energy in this form? Our goal is to contribute to the literature by revealing a mistake that is known to be true. For this purpose, both theoretical and empirical analyses were conducted based on “biofuel production” and “agri-food prices.” The United States, the world’s largest producer of biofuels, was selected for empirical analysis. In this context, the ARDL model of long-term and short-term relationships between variables was decoded using data containing 1992-2017. The findings revealed the existence of a long-term linear relationship between the two variables.

**Keywords:** Biofuels, Agri-Food Prices, Renewable Energy

**JEL Classifications:** Q4,Q3,C1

### 1. INTRODUCTION

Energy has taken a very important position in today’s world. On the one hand, with the growth of the population, on the other hand, with the development of technology, the need for energy increases every day. Currently, a significant part of energy needs is met from fossil fuels. But fossil fuels are scarce resources. Fossil fuels, which have a history of about two hundred years, now give signs of depletion. Therefore, the orientation to alternative energy sources has begun. In this context, renewable energy sources are preferred.

Renewable energy, often called clean energy, is derived from natural sources with continuity. For example, sunlight or wind

continue to shine and blow even if their presence depends on time and weather. Non-renewable or “dirty” energy includes fossil fuels such as oil, gas and coal. Non-renewable energy sources exist only in limited quantities and take a long time to regenerate (NRDC, 2021). Recently, one of the preferred renewable energy sources is biofuels.

Currently, biofuels are defined as renewable energy in the literature. But biofuels are fuels of biological origin that depend on agricultural production. The fact that biofuel production is at the expense of greater use of earth and ecosystem services (Susan et al., 2010) has led to some debates. Discussions on the use of biofuels often focus on potential competition with food crops and the negative effects of converting land from current

agricultural use to the production of bioenergy crops (Davis et al., 2012). Biofuel raw materials contain many crops that will be used directly or indirectly for both animal feed and human consumption. Diverting these crops to biofuels leads to more land area devoted to agriculture, increased use of polluting inputs, and higher food prices (EPA, 2021).

According to these facts, is it correct to define biofuels as renewable energy? Our goal is to uncover a mistake known to be correct, to contribute to the literature. This claim reveals the authenticity of the study, its difference from other studies. In order to support our claim, both theoretical and empirical analyses of the relationship between biofuel production and food prices have been conducted. Theoretical analysis was carried out using opportunity cost and demand curve. ARDL cointegration model was used for empirical analysis. The study covers the period between 1992 and 2017. A study was conducted in the US private, the world's largest biofuel producer, considering whether the increase in food prices in recent years has anything to do with biofuel production.

## 2. LITERATURE REVIEW

In the literature, there are numerous studies on the impact of biofuel production on agri-food prices. Many of these studies have also found that biofuel production increases food prices. Some studies on this subject are as follows.

From March 2007 to March 2008, the prices of some grain products have more than doubled in the world, leading to a controversy that these increases are related to biodiesel production. Thereupon, Sherry et al. (2011) conducted a study. Accordingly, current analyses have shown that biofuel production contributed modestly (3-30%) to the increase in food prices observed until mid-2008. Ajanovic (2011) observed in his study that biofuel production does not have a significant impact on raw material prices. In addition, it is possible to come across similar studies that suggest that food prices will increase if biofuel production becomes widespread (Nonhebel, 2012; Kgathi et al., 2012; Naylor et al., 2007). Singagerda et al. (2018) aimed to analyse the impact of palm oil-based biodiesel development on growth and poverty in Indonesia that combined with the government. The study found that palm oil-based biodiesel development can create growth and poverty in Indonesia. Similarly, Roder (2016) found that the use of raw materials for biofuel purposes could increase the price of food. Abbott (2014) concluded that about half of the increase in corn prices in the period between 2005 and 2009 was due to biofuel production. Zhang et al. (2009) investigated the volatility of wholesale prices of corn, ethanol, soybeans, gasoline, and oil for the period between 1989 and 2007 for the United States. Accordingly, increases in ethanol prices affect agricultural commodity prices in the short term. Kristoufek et al., (2013) analysed the relationship between biofuel and food prices for the United States and the European Union (EU) between 2003 and 2008. According to the results, there are significant links between biofuels and food prices. Al-Riffai and Nistor (2010) general equilibrium analysis investigated the impact of EU and US biofuel directives on final food prices. They found that EU biodiesel guidelines had a strong impact on agricultural commodity

prices. Gombkötő (2014) his study showed that the increase in biofuel production is affecting global food prices. Fabiosa et al. (2009) conducted a study measuring the impact of the emergence of biofuel markets on the U.S. and World Agriculture. In the US., changes in the coarse grain prices of biofuels affect wheat and oilseeds prices, all of which are transmitted to world markets. It also has global impacts on land allocation. (Trostle, 2008; Gamborg et al., 2012; Das, 2020), in its study, argued that the use of food grains as raw materials for biofuel production hinders the food supply of needy people and negatively affects food prices.

## 3. THEORETICAL ANALYSIS

Mainstream economics is defined as a branch of science that combats scarcity. This is because the resources are limited. Limited goods are also products that can be depleted. The effective distribution of limited resources depends on the price mechanism. Thanks to the price mechanism, most of society benefits from these goods and services in the long term. As the resource supply shrinks, the increase in demand is balanced by price increases. Such goods are defined as economic goods. There are also inexhaustible goods. Mainstream economics defines inexhaustible goods as free goods. Free goods are goods that are already available in nature that do not require an effort and do not have a shortage problem. Because there is no shortage problem, their pricing is also out of the question. For example, the air we breathe, the sun, the wind, etc. are examples of free goods. These goods are also defined as renewable energy sources. It is preferred as an alternative to fossil fuels with a history of about 200 years.

All sources, except fossil fuels, are almost expressed as renewable energy. One of them is biofuels. Biofuels contain energy-rich chemicals that are produced directly through biological processes or derived from chemical conversion from the biomass of previous living organisms. Biofuels are mainly produced from photosynthetic organisms such as photosynthetic bacteria, micro and macroalgae, and vascular land plants (Rodionova et al., 2017). However, the rapid growth of biofuel production is seen as a particular sustainability issue and a threat to food security. Accordingly, the expansion of first-generation biofuel production threatens the availability of adequate food sources for humans by diverting soil, water and other resources from food and forage crops. (Fischer et al., 2009). Many Asian countries, especially the United States (USA), European Union (EU) countries, and Brazil have turned to biofuel production. However, the explosion in agricultural prices and the food crisis in 2007-2008 that followed it has seriously devalued the public image of biofuels due to their potential negative impacts on world's food safety in the context of land shortage (Hervé et al., 2010).

If the increases in food and energy demand continue in this way, it is expected to put more pressure on biodiversity and ecosystem services (Correa et al., 2017). With the world's population projected to rise to nine billion by 2050, food demand is expected to increase by more than 60% compared to 2006 levels (FAO, 2016). This shows that approximately 70 million hectares of cultivated land will be needed (Alexandratos and Bruinsma, 2012). The allocation of agricultural land for food production to biofuel

production during an increasing period of the human population will first affect food prices. In this context, the effect of biofuel production on food prices is shown in Figure 1.

The charts are presented in two categories: A and B. Chart A shows biofuel production on the vertical axis and agricultural production for food on the horizontal axis. This has been shown on the opportunity cost curve in mainstream economics. Accordingly, to produce one unit of biofuel, it is necessary to give up the same amount of agricultural production. Chart B includes price on the vertical axis and agricultural food production on the horizontal axis. In order to demonstrate the impact of biofuel production on agri-food prices, the demand curve was used. Accordingly, agricultural production decreases at point “A,” where biofuel production is the highest, and the product price is at the highest level (Point C). Similarly, at Point “B,” where biofuel production is minimal, agricultural production is lowest at the highest prices (Point D).

## 4. EMPIRICAL ANALYSIS

### 4.1. Data Set and Method

The study used data on biofuel production and agricultural product prices for the United States (USA). In the United States, the use of biofuels has become widespread with the Renewable Fuel Standard (RFS) policies. In this process, the fact that biofuels are naturally carbon neutral and their greenhouse gas emissions are less than fossil fuels have been effective (De Cicco et al., 2016). Although agricultural commodity prices in the United States change frequently from year to year, they generally have a tendency to rise since the 2000s. Inflation-adjusted prices for crops in the period 2006-2018 were 38% above 2005 levels. In this process, crop prices increased, while productivity in production decreased compared to the last century. It is predicted that the rise in prices will continue with the slowdown in population, income growth and the increase in biofuel production. (USDA, 2021). Data for the variables are taken from the food and Agriculture Organization Corporate Statistical Database (FAOSTAT) and the United States Department of Agriculture (USDA) datasheets. The study used annual data for the period between 1992 and 2017. Since there was a 2008 global crisis during this period, the dummy variable was prepared to include the impact of this crisis in the model.

Pesaran et al., (2001) ARDL boundary test that they have developed was used as a method in the study. The most important

advantage of the ARDL boundary test approach is that it can be applied regardless of whether the variables included in the analysis are I (0) or I(1). Another plus of the ARDL test is that it can give more accurate and reliable results compared to classic co-integration tests, thanks to the unconstrained error correction model it uses. Perhaps the most crucial feature of the error correction model is that it contains information about the current long-and short-term dynamics between series (Akel and Gazel, 2014). According to Narayan and Narayan (2006), the test results of the ARDL method are more effective than the test results of classical cointegration methods. Furthermore, this method gives better results in small samples.

In the ARDL approach, variables must be stationary of the maximum first order. In our model;

**Dependent variable:** Agri-Food Prices (AFP)

**Independent variable:** Biofuel Production (BF)

First, the logarithm of the variables was taken. The reason for taking the logarithm is that it brings data in the form of multiplication to the form of addition, i.e. linear format (Kutlar, 2017). Unit root test was performed for the series whose logarithm was taken. Later, a number of diagnostic tests were performed, such as specification tests (autocorrelation, varying variance.) The cointegration relationship between the variables is formulated as follows.

Cointegration Relationship:  $\text{Log (AFP)} - [3.0576 \text{ Log (BP)} + 7.6670]$

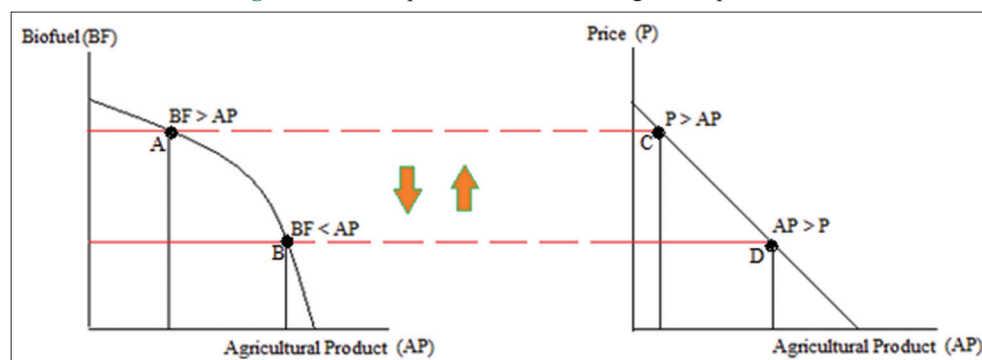
## 5. EMPIRICAL RESULTS

First, descriptive statistics were included. The results of the application were then included. Descriptive statistics for variables are given in Table 1.

The probability values of the variables were greater than 0.005. This shows the normal distribution. After the descriptive statistics, the correlation coefficients between variables are as in Table 2.

Our correlation coefficient was 0.554. The probability value is 0.0033. The correlation coefficient varies between  $-1$  and  $+1$ . As we get closer to one, the strong correlation between the variables

**Figure 1:** Biofuel production relation to agri-food prices



and the positive sign of the coefficient indicate that the variables move in the same direction.

At the next stage, a unit root test was performed to determine whether the variables were stationary. It was found that the level values of the variables contained a unit root, and they were made stationary by taking their first difference. The stationaries of the variables to be used in the analysis were tested with Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, and the results are shown in Table 3.

The first differences of the variables found to contain a unit root at the level were made stationary.

According to Table 4, the H0 hypothesis was rejected because the statistical value of F (4.4461) calculated at the 5% significance level is greater than the upper limit (4.16). According to this, it was detected that there is a cointegration relationship between the variables.

The existence of a long-term equilibrium relationship between variables was determined by the F test. After that, parameters reflecting the long-term relationship need to be estimated. The results of the method estimated using the least squares (Eck) method are as shown in Tables 5 and 6.

According to the results in Table 5, the LOGBF coefficient, which is a long-term explanatory variable, is positive and significant. The long-term coefficient is 3.057554. Accordingly, we can say that a 1% increase in biofuel production leads to a 3% increase in agricultural product prices. This result shows that biofuel production in the US during the relevant period had a significant and positive impact on agri-food prices.

When the diagnostic test results of the model are evaluated, it is seen that, according to the Breusch-Godfrey LM test results, there

**Table 1: Descriptive statistics about variables**

Statistics	BF	AFP
Mean	8.997308	90.19769
Median	9.120000	88.00000
Maximum	9.980000	184.3400
Minimum	7.270000	50.87000
Std. Dev.	0.783109	35.79257
Skewness	-0.668810	1.024754
Jarque-Bera	2.492489	4.748785
Probability	0.287583	0.093071
Sum	233.9300	2345.140
Sum Sq. Dev.	15.33151	32027.69
Observations	26	26

**Table 2: Correlation coefficients of biofuel production and agri-food prices**

Correlation		
Probability	BF	AFP
BF	1.000000	
	----	
AFP	0.554903	1.000000
	0.0033	----

is no autocorrelation in the model, according to the Jarque-Bera test results, the error term is normally distributed, according to the White test results there is no variance problem in the model, and the model is established with the correct specifications according to the Ramsey Reset Test results. Therefore, these results support that the estimated results obtained are reliable. Finally, to avoid testing the stability of ARDL long-term coefficients, Cusum and Cusumq graphs developed by Brown et al. (1975) are shown in the Figure 2.

According to the Cusum and Cusumq test, the estimated parameters are stable if the curves obtained as a result of the test statistics for error terms are within critical limits at the 5% significance level. When evaluating the graphs in the figure, it was concluded that the parameters obtained as a result of ARDL long-term prediction are stable.

An error correction model based on the ARDL approach is being established to decipher the short-term relationship between variables. In Table 6, the variable CointEq (1) is a period lagged value of the series of error terms obtained from the long-term relationship. The coefficient of this variable indicates how many deviations from the equilibrium in the short term will be corrected in the long term. It is predicted that this coefficient is statistically significant, and its sign is negative.

**Table 3: Unit root test results**

Variables	ADF		AFP	
	t statistics	Prob.	t statistics	Prob.
BF	-4.868049	0.0045	-12.40432	0.0000
AFP	-5.955040	0.0001	-15.56872	0.0000

**Table 4: F statistics and critical values**

Model	K	M	F statistics	Severity level	Low. bound	Upp. bound
ARDL (1,4)	1	4	4.4461	%1	3.02	3.51
				%5	3.62	4.16
				%10	4.94	5.58

**Table 5: Long-term coefficients estimated based on the ARDL (1,4) model**

Variable	Coefficient	t statistics
LOGBF	3.057554	1.240185*
Diagnostic test results		
R <sup>2</sup>	0.7876	Normality <sup>b</sup>
Adj R <sup>2</sup>	0.7103	Changing variance <sup>c</sup>
Autocorrelation <sup>a</sup>	0.7409	Model building <sup>d</sup>

**Table 6: ARDL (1,4) Error correction model prediction results**

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D (LOGBF)	-0.182152	0.304039	-0.599109	0.5639
D (LOGBF(-1))	-1.334740	0.551072	-2.422081	0.0385
D (LOGBF(-2))	-1.400320	0.331644	-4.222353	0.0022
D (LOGBF(-3))	-0.759843	0.235989	-3.219821	0.0105
CointEq(-1)*	-0.622568	0.154192	-4.037624	0.0029

\*0.05 shows statistical significance at the importance level



Figure 2: Cusum test graph

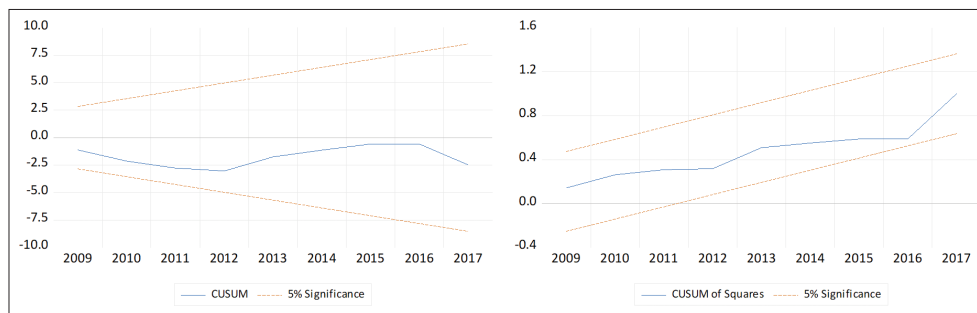


Table 7: Biofuels comparison with renewable energy sources

Criteria	Biofuels (Raw material of plant origin)	Renewable energy (Sun, Wind, Water)
Raw material production	It needs to be specially produced. It requires manpower	There is no need for humans. Production continues, even if there is no human
Raw material price	Price	No price
Cost	Its production has an opportunity cost. For the production of one unit of biofuels, agricultural production for food must be abandoned	No opportunity cost
Famine problem	Arable land production depends on the volume. There is a problem of shortages in the long term. Even if it is exhausted, it does not break the vital cycle. (Such as fossil fuels)	Abundantly available, depletion is not possible. If it is exhausted, all vital activities will cease
Waste problem	It can leave waste, just like fossil fuels. It is harmful to the ecosystem in the long run	No waste problems. It has no negative impact on the ecosystem

In the table,  $\text{CointEq}(-1)^* (-0.622568)$ , coefficient value  $(-)$  probability value  $<0.05$ , significant. Accordingly, our error correction model works. If there is a deviation between the variables in the long run, the next period approaches each other by 63%.

## 6. DISCUSSION

It is essential that renewable energy sources are produced from sources that can renew themselves one hundred per cent. In other words, it should be completely free goods. Free goods are goods obtained without effort, which are abundant in nature. Therefore, free goods are goods that cannot be priced or have no price problem. The situation for biofuels is slightly different, soil is required for biofuel production. It is a natural resource that can be depleted. As the amount of cultivable land decreases, the price of biofuels will increase. In this regard, price indices were preferred as the dependent variable in the study. For all these reasons, biofuels are not qualified to be renewable energy.

To better understand this situation, the properties of biofuels and the properties of renewable energy sources are compared in the Table 7 below.

When the table is examined, it is possible to see clearly that biofuels do not have the basic properties that renewable energy sources have. In this context, biofuels do not have long-term sustainable properties in terms of energy supply. In this respect, biofuel production should be abandoned and instead, more efficient energy production with high added value should be preferred.

## 7. CONCLUSION

In the literature, biofuels are defined as a type of renewable energy. Based on the properties of biofuels, a study was desired to test the accuracy of this detection. To support our claim, both theoretical and empirical analyses of the relationship between biofuel production and food prices have been conducted. Theoretical evidence has been made using the opportunity cost curve and the demand curve. For empirical evidence, it has been considered whether the increase in food prices seen in recent years in the United States, the world's largest producer of biofuels, has anything to do with biofuel production.

According to the results of a theoretical analysis using the opportunity cost curve and the demand curve; for one unit of biofuel to be produced, the same amount of agricultural production must be given up. The effect of this relationship on prices: agricultural production decreases in the period when biofuel production is highest, and the price of the product is at the highest level. Similarly, in periods when biofuel production is minimal, agricultural production is at the most and prices are at the lowest level. On the other hand, according to the results of the empirical analysis conducted by establishing an ARDL cointegration model for the United States, a long-term relationship between biofuel production and food prices in the United States was detected. Accordingly, during 1992-2017, biofuel production in the United States increased, while food prices also increased.

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