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DRIVERS OF LIQUID BIOFUEL PRICES IN POLAND

Key words: biofuels, policy, prices, exchange rate, crude oil, legal regulations, Poland, renewable energy sources

ABSTRACT. The general aim of the study was to determine the impact of legal regulations in force on the market of liquid biofuels and biocomponents in Poland on the prices of fatty acid methyl esters (so-called biodiesel or BIO100 biofuel). Therefore, we indicated the importance of legal regulations in shaping biodiesel prices in Poland based on empirical data from the period of 2008-2016 (the latest available data). An additional purpose was to assess the legal regulations as drivers of ecodiesel (diesel with an admixture of biodiesel) prices in Poland based on empirical data from the period 2004-2021. Institutional, legal and economic variables were distinguished, assuming that the biofuel market, like many other markets, is so heavily regulated that taking legal acts into consideration is crucial for its functioning. Multiple regression analysis was used. The sources of data were officially available databases (PKN Orlen Data, FRED Economic Research Data, as well as USD/PLN exchange rate quotations), while the sources of legal acts were the Journal of Laws of the Republic of Poland and the Official Journal of the European Union. The obtained results indicated that the prices of biofuels (specifically biodiesel) in Poland depend both on economic factors (the USD/PLN exchange rate and crude oil prices) and on some legal regulations, including domestic and EU regulations. We proved the importance of the EU directive 2003/30 on the promotion of the use of biofuels or other renewable fuels for transport, as well as acts on renewable energy sources (2015), on amending the act on liquid biocomponents and biofuels (2014) and on excise duty (2008).

INTRODUCTION

The first two decades of the 21st century were a time of dynamic development of the liquid biofuels sector, both in Europe and the World. This sector of the economy is an important element of the development of agriculture as a whole and now, to a certain extent, drives the situation of some agricultural subsectors (the production of certain plants, e.g., oilseeds). Despite the declining importance of agriculture in the economy, globally, its role is still very important, especially in the context of striving for sustainable development

not only of agriculture itself, but also of the economy, environment and society. The desire to reduce global carbon dioxide emissions, the attempt to make the world economy independent of fossil fuels and the need to diversify energy sources are the most important economic development factors for the liquid biofuels sector. Potentially, increasing the consumption of liquid biofuels, both of the first generation (produced with the use of edible agricultural products) and next generations (produced with the use of inedible and waste or non-agricultural products) may be a significant factor contributing to the reduction of the use of fossil fuels, e.g., in transport. According to Tomasz Rokicki et al. [2021a], the sustainable development of transportation requires, inter alia, using clean fuels. At the same time, attention should be paid to the possible impact of the biofuel sector on the prices of agricultural products, because of the demand pressure on the market of agricultural raw materials [De Gorter et al. 2013, Piwowar 2015, Borychowski, Czyżewski 2017]. Figure 1 shows the production volume of liquid biofuels (bioethanol and biodiesel) on a global scale in the years 2000-2016. The production of bioethanol prevails mainly because the largest quantities of this biofuel are mainly produced in the USA and Brazil, while biodiesel is produced in the greatest quantity in the European Union. In turn, Figure 2 presents the production and consumption of biodiesel in Poland, one of the main producers of this biofuel in the European Union.

Climatic conditions, which determine the type of agricultural production, the scale and scope of economic policy in the sector and, finally, various social conditions that affect the structure of farms – potential biofuel producers, are also of great importance in this matter.

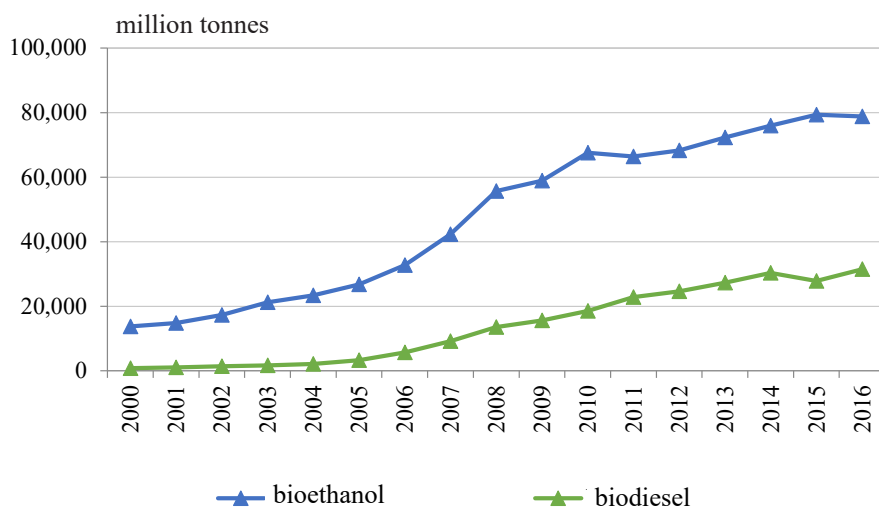


Figure 1. Production of biofuels worldwide

Source: own elaboration based on [FRED 2021]

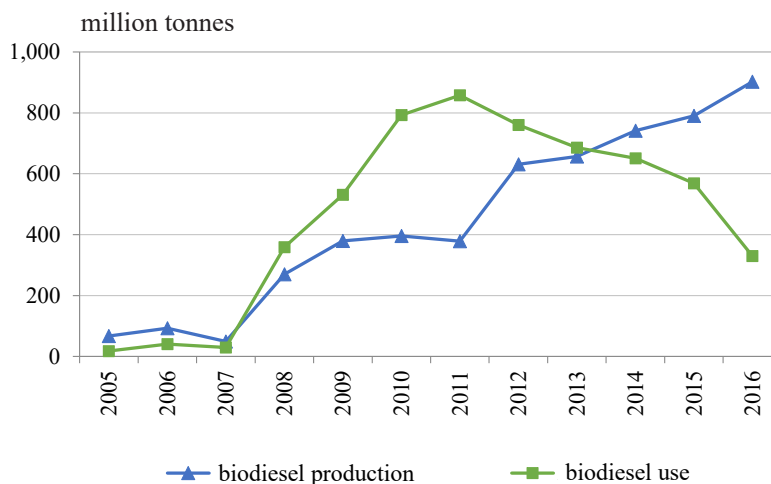


Figure 2. Production and use of biodiesel in Poland

Source: own elaboration based on: [FRED 2021]

An extremely important aspect of the sector's development is also the climate and energy policy of the European Union, including Poland. Possible support for the development of biofuels at an administrative and a political level may play a key role in the economic position of the biofuels sector. As noted by Aldona Skarzyńska (ed.) [2013], regulations undoubtedly determine the development of this branch, but they are not necessarily expressed in the form of specific benefits, as it is in the context of economic factors. Łukasz Chmielewski and Witold Rodkiewicz [2010] emphasize that, for the biofuel industry, the economic margin is a key factor only in the short term, while, in the long term, the most important factor is the policy towards the sector and the system of legal regulations. This leads to the following conclusion, a predictable and reasonable biofuel policy can ensure the stable development of the sector, while instability can cause problems, also leading to production cessation [Jarosz, Faber 2016]. Therefore, only taking both political (legal) and economic factors into consideration can a more complete picture of the situation of the liquid biofuels sector and the determinants of its changes be obtained.

The general aim of the study was to determine the impact of legal regulations in force on the market of liquid biofuels and biocomponents in Poland on the prices of fatty acid methyl esters (so-called biodiesel or BIO100 biofuel). Therefore, we indicated the importance of legal regulations in shaping biodiesel prices in Poland based on the empirical data from the period of 2008-2016 (the latest available data). The additional purpose was to assess the legal regulations as drivers of ecodiesel (diesel with an admixture of biodiesel) prices in Poland based on the empirical data from period 2004-2021. Therefore, our motivation

was to check whether changes in legal regulations concerning the liquid biofuels sector are key to their prices, or whether these prices are determined by other factors. Hence, the impact of economic and non-economic factors, understood as legal acts regulating the liquid biofuels sector, both at a national and EU level, was examined. Such an approach to the problem is unique in literature. The authors are aware that legal regulations, apart from the abovementioned economic issues, are not the only factor influencing biodiesel prices. However, our motivation was to examine this aspect. Additional determinants of biodiesel (and more broadly – biofuels) prices are the amount of agricultural raw materials, production costs and taxes [Duff 2013, Amin et al. 2017, Irwin 2021].

On the basis of economic theory, the research concerns those views that consider interventionism to be necessary in achieving goals that a market without interference could not achieve, including various environmental demands (emission reduction and decarbonization in transport). State intervention is, thus, manifested in the provision of legal regulations for the liquid biofuels sector, which would not have a chance to develop without this framework and direct support from public funds. Moreover, research can be embedded in the context of environmental economics, which suggests the perception of the environment as a system with its own limitations, but at the same time gives priority to economic goals over environmental targets. A completely different view on this issue is presented by ecological economics, which gives priority to environmental issues, also over economic ones. This is to create opportunities for achieving a long-term balance between environmental and economic issues [Czaja 2012, Borys 2013, Matuszczak 2013, Prandecki 2014]. Certain elements of environmental protection in its assumptions and considerations are also included in institutional economics, in which both formal and informal institutions play a key role. They can help in making decisions in some areas that are particularly important from a social point of view, such as environmental protection [Prandecki 2007].

RESEARCH MATERIAL AND METHODS

We used data from several sources to investigate the impact of legal regulations on biodiesel (BIO100) prices in Poland. Figure 3 depicts biodiesel prices in Poland in 2008-2016 in PLN/m³. The prices of biodiesel and ecodiesel were taken from the database of PKN Orlen. Daily quotations recorded were averaged to monthly data. For biodiesel prices, the time frame is 2008-2016 (the latest available), while ecodiesel prices were recorded in the period January 2004 to March 2021. Legal regulations have been treated as follows – the validity of a legal act in a given period has been assigned to binary variables (value 1 for the regulations in force). The date of entry into force of the act was considered to be the moment the President signs the act or, in the case of European Union legal acts, the date of the directive. The analysis included regulations that relate to the

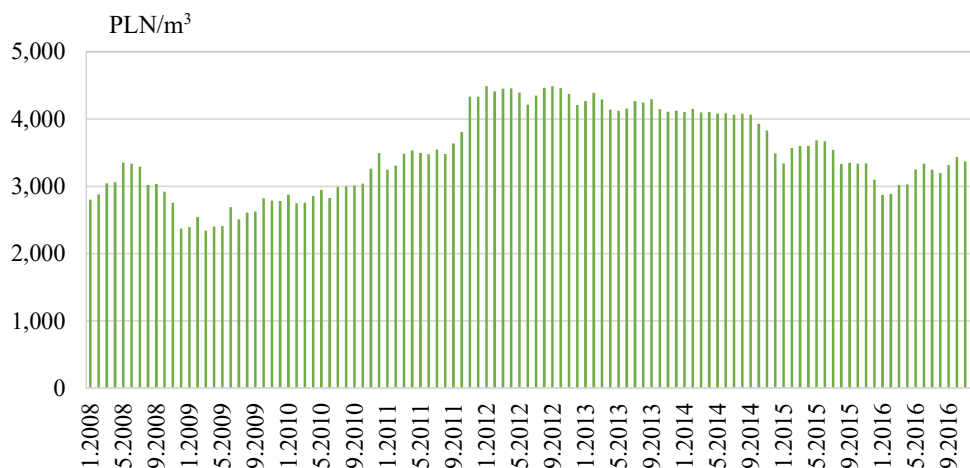


Figure 3. Prices of biodiesel (BIO100) in Poland

Source: own elaboration based on [PKN Orlen 2021]

liquid biofuels market, therefore mainly act on liquid biocomponents and biofuels with later changes, on excise duty, fuel quality monitoring, the control system and renewable energy sources. Apart from binary variables, non-binary variables representing important economic factors influencing the prices of liquid biofuels were also used in the study. These are the monthly averaged exchange rate USD/PLN and the average monthly prices of Brent crude oil. The source of these crude oil prices is the Federal Reserve Economic Data (US Energy Information Administration), while legal acts come from the following sources – for Poland only – from the Journal of Laws of the Republic of Poland, and valid throughout the European Union – from the Official Journal of the European Union. Detailed data with the sources used in the empirical study are presented in Table 1.

To investigate the impact of the aforementioned variables on biodiesel prices in Poland, as described, the presented data were collected into monthly time series covering the period 2008-2016. Data from the period 2004-2021 were used to determine the determinants of ecodiesel prices. The multiple regression model was applied using classical least squares. The formula of the model is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_n X_n + \varepsilon$$

where: Y – change in BIO 100 prices in Poland, X_1 – change in the USD/PLN exchange rate, X_2 – the change in the crude oil price (Brent), in Europe, X_3, \dots, X_n – regulations on the liquid biofuels market, β_0, \dots, β_n – parameters, ε – error term.

Table 1. The variables used in the analysis and sources of data

Variable	Abbreviation	Source
BIO100 price in Poland [PLN/m ³]	BIO100	PKN Orlen
Relative change in the BIO100 price in Poland	Change in BIO100 price	
Ecodiesel price in Poland [PLN/m ³]	Ecodiesel	
Relative change in the ecodiesel price in Poland	Change in ecodiesel price	
USD/PLN Exchange rate (monthly, average)	USD/PLN	Investing.com
Relative change in the USD/PLN exchange rate	Change in USD/PLN	
Crude oil prices in Europe (Brent, USD/barrel)	Brent price	FRED Economic Research Data
Relative change in the crude oil price (Brent), in Europe	Change in Brent price	
The Act of 23 January 2004	EXCISE 2004	Journal of Laws of the Republic of Poland
The Act of March 11, 2005	BIO 2005	
The Act of August 25, 2006	BIO 2006	
The Act of December 6, 2008	EXCISE 2008	
The Act of February 20, 2009	ENER 2009	
Act of March 21, 2014	BIO 2014	
The Act of January 15, 2015	BIO 2015	
The Act of February 20, 2015	RES 2015	
The Act of November 24, 2017	BIO 2017	
The Act of November 24, 2017	BIO 2018	Official Journal of the European Union
Directive 2003/30/EC	DIREC 2003	
Directive 2009/28/EC	DIREC 2009	

Source: own elaboration

The indicated time series were tested for stationarity. An upward trend was observed for BIO100 prices, described by the equation $y = 0.282x - 8,110$, while for ecodiesel prices, the equation was $y = 0.2x - 4,767$. The situation (an upward trend) is similar in the context of the USD/PLN exchange rate. To obtain stationary series for further research, the relative and absolute increments of the studied variables were analyzed, with the final focus on relative changes. To confirm the obtained results, the Augmented Dickey-Fuller test was used in the further part of the study. Testing was performed for a twelfth order lag using monthly observations. Each series was tested both with the intercept and separately with the intercept and the linear trend. For the series of biodiesel and ecodiesel price changes,

Table 2. The results of the Augmented Dickey-Fuller Test (ADF) for stationarity

Specification	ADF test with constant	<i>p</i> -value	ADF test with constant and trend	<i>p</i> -value
BIO100	-0.100	0.6173	-0.019	0.8885
Change in BIO100 price	-0.003	0.0007	-0.003	0.0048
Ecodiesel	0.005	0.13	0.004	0.33
Change in ecodiesel price	0.001	8.78 ^{E-23}	0.001	1.63 ^{E-22}
USD/PLN	0.014	0.2424	-0.010	0.01
Change [USD/PLN]	0.001	9.83 ^{E-08}	-0.001	8.65 ^{E-07}
Brent price	0.012	0.04	0.013	0.13
Change in Brent price	-0.012	1.06 ^{E-18}	-0.012	3.86 ^{E-19}

Source: own elaboration based on mentioned data

the results are as follows: the autocorrelation of first-order residuals does not exceed a level of 0.007; the value of the tests indicates statistical significance and falls within the accepted tolerance level for a *p*-value of 0.05; the explanatory variables were tested in a similar way. The exact results are presented in Table 2.

RESEARCH RESULTS AND DISCUSSION

Table 3 shows the results of the regression analysis for the model, which was described in the previous section. The estimated model is characterized by the coefficient of determination R^2 and corrected R^2 at the level of – respectively – 0.61 and 0.59, which can be considered as satisfactory values, considering the complexity of the analyzed matter. The *p*-values for the Breusch-Pagan/Cook-Weisberg and White tests (below Table 3) indicate no reasons for rejecting the null hypothesis, so there is homoscedasticity in this model and the variance is constant. There are given values for the Root Mean Square Error as well as Akaike information criterion and Bayesian information criterion.

The results prove that the changes in biodiesel prices in Poland were influenced by both economic factors and legal regulations. All of them are statistically significant at an 0.01 level. The economic aspects include changes in the USD/PLN exchange rate and Brent crude oil prices. The values of regression coefficients are positive, which means that increases in crude oil prices and the appreciation of the USD led to increases in biodiesel prices. The positive impact of crude oil prices on biofuel prices is also indicated by reports prepared by the Food and Agriculture Organization of the United Nations [FAO 2008], International Energy Agency [IEA 2020].

Table 3. The results of the multiple regression analysis with robust standard errors: determinants of the relative change in the biodiesel (BIO100) price in Poland

Y = change in BIO100 price in Poland	Coefficient	Std. error	t	P > t	[95% Conf. Interval]	
Change [USD/PLN exchange rate]	0.4587011	0.0791737	5.79	0	0.3016418	0.6157604
Change in Brent price	0.4103228	0.0331123	12.39	0	0.3446369	0.4760087
DIREC 2003	-0.0397814	0.0122670	-3.24	0.002	-0.0641159	-0.0154470
EXCISE 2008	-0.0418075	0.0132999	-3.14	0.002	-0.0681910	-0.0154241
BIO 2014	-0.0431390	0.0143443	-3.01	0.003	-0.0715942	-0.0146838
RES 2015	-0.0490594	0.0149780	-3.28	0.001	-0.0787717	-0.0193472
cons	0.0459562	0.0137441	3.34	0.001	0.0186916	0.0732207
Number of observations	108					
F (6, 101)	26.81					
Prob > F	0					
R-squared	0.6143					
Adjusted R-squared	0.5914					
Root Mean Square Error	0.02723					
Akaike information criterion	-465.1054					
Bayesian information criterion	-446.3305					

Breusch-Pagan/Cook-Weisberg test for heteroscedasticity:
 $\chi^2(1) = 1.52$, Prob > $\chi^2 = 0.2182$.

White's test for H0: homoscedasticity:
 $\chi^2(18) = 13.64$, Prob > $\chi^2 = 0.7523$

Source: own calculation based on mentioned data

Four of the analyzed legal acts turned out to be statistically significant. They are Directive 2003/30 of the European Parliament and of the Council on the promotion of the use of biofuels or other renewable fuels for transport, the Act of 2008 on excise duty, the Act of 2015 on renewable energy sources, as well as the Act of 2014 amending the Act on liquid biocomponents and biofuels and some other acts. All these regulations impacted biodiesel prices in the same way, i.e., their introduction contributed to the decline in the changes of biofuel prices in Poland.

Many authors emphasize that the policy of supporting the biofuel sector is one of the key factors determining its development [Abbott et al. 2008, OECD-FAO 2008-2017, McPhail, Babcock 2012, Kim et al. 2013, Hamulczuk 2014, Szajner 2015, Kagan 2016, Ruciński 2016]. Therefore, we could claim that the policy created the market. To explain the significance of the indicated legal acts for biofuel price changes in Poland, regulations were analyzed.

From the perspective of the EU common market, of which Poland became a part of (EU accession May 1, 2004), the most important were the directives of the European Parliament and the Council, which comprehensively regulated the functioning of the liquid biofuels sector in the EU. The first directive that was fully devoted to the liquid biofuels sector was Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport. The primary goal set out in this directive was to increase the use of biofuels in transport for the implementation of the sustainable development strategy. The tools were: to promote activities related to the expansion of EU production capacity in the biofuel sector and encourage private and institutional entities in the EU to use more biofuels in the place of fossil fuels. Moreover, the document obliged Member States to create indicators concerning national blending mandates for the share of biofuels in fuel consumption in transport. It can, therefore, be concluded that this directive created the basic institutional and legal framework for the liquid biofuels market and planned a development trajectory for several years. This was reflected in the increase in the production and consumption of biofuels, as well as in the dynamic development of the sector.

Statistical significance in the model was also demonstrated by the Amendment to the Excise Tax Act of 2008. Its content mainly concerned the organization of trade in excise goods (including fuels) and their labeling. Excise tax issues may be important in the context of international competition between producers from different countries and production profitability, as mentioned by Zuzanna Jarosz and Antoni Faber [2016]. The Act on liquid biocomponents and biofuels of 2014 mainly concerned the implementation of the Directive of the European Parliament and of the Council of 2009 on the promotion of the use of energy from renewable sources. A specific issue raised by the directive, which required a special implementation in national law, was the requirement to use a 10% share of renewable energy in transport by 2020. This supported the industry and stabilized its development, while showing the final target for 2020. The Act on renewable energy sources of 2015 concerns the adjustment of legal solutions adopted in Poland to the legislative standards of the renewable energy market in force in other leading EU countries. It was aimed at, inter alia, increasing energy security and environmental protection, the rational use of renewable energy sources, shaping mechanisms and instruments supporting the production of electricity, heat or cold, or agricultural biogas in renewable energy source installations and the development of optimal and sustainable energy supply to end users. The act on renewable energy sources was long awaited by the market. Hence, it was another document that emphasized the importance of liquid biofuels.

An additional part of the research was to determine the impact of economic factors (USD/PLN exchange rate, crude oil prices and biodiesel prices) and changes in legal regulations on the prices of ecodiesel, i.e., diesel oil with an admixture of biocomponents. As indicated earlier, the share of this admixture results from legal regulations in Poland and in the analyzed period it reached several percent, hence, of course, the prices of biodiesel

do not have to be the key factor. Regression analysis showed, however, that changes in the prices of biodiesel (BIO100), apart from changes in the USD/PLN exchange rate and changes in crude oil prices (Brent), had a positive impact on changes in the prices of ecodiesel (both in 2008-2016 and 2004-2021). Interestingly, none of the analyzed legal acts related to the biofuel industry was statistically significant for changes in ecodiesel prices. This means that biofuel market regulations only have a direct effect on biodiesel prices but have no effect on the prices of ecodiesel.

As the biofuel market in Poland is part of a wider market – the entire European Union, Polish law is regularly adjusted to EU regulations. In this context, currently the biggest challenge in this aspect is the Directive of 2018 on the promotion of the use of energy from renewable sources [Directive 2018/2001]. As mentioned, the Polish biofuel market is still largely based on biofuels produced from edible agricultural raw materials, hence changes in the regulations aimed at promoting biofuels from non-food raw materials may pose a significant threat to the operation of the Polish sector in the future. It is also worth noting that the Polish production of liquid biofuels is characterized by little use of production potential, which in the case of bioethanol is only 27%. For methyl esters it is already 57%, but it is still a relatively low value and significantly differs from the results achieved in Western European countries [Kupczyk et al. 2017a].

The studies of Piotr Borowski et al. [2016], Adam Kupczyk et al. [2017a] and Joanna Mączyńska et al. [2019] showed that the investment attractiveness of the biofuel sector in Europe and the world is clearly decreasing, which may indicate a certain saturation of the market, and this may indirectly affect the interest of EU market entities in new, innovative production methods and influence the levels of market prices. One solution to this problem may be the shift from first-generation biofuels to next-generation biofuels that use non-food raw materials. On the EU market, the production of lignocellulosic bioethanol looks favorable in this respect, but the production technology is still highly expensive and requires a lot of capital. The production of advanced biofuels of higher generations still does not take place in Poland at an industrial level [Gradziuk, Jendrzewski 2017]. The use of marine algae rich in oils suitable for biodiesel is now also highly hoped for, but due to the still inadequate technical parameters of the biofuel obtained in this process, its application to current standard diesel engines seem to still be impossible. Work is currently underway to improve the methods of refining this oil, so that its use in industry is realistic in the near future [Borowski 2016]. The need for a shift in EU biofuel policy towards non-agricultural and non-food raw materials is also emphasized by Piotr Gradziuk and Błażej Jendrzewski [2017], Zuzanna Jarosz and Antoni Faber [2016], Adam Kagan [2016] and Adam Kupczyk et al. [2017b]. Moreover, the competition for agricultural raw materials (especially rapeseed) between agriculture and energy sectors may be seen as an argument for the withdrawal of political support for the biodiesel sector [Gradziuk et al. 2021].

The report of the Ministry of Economy on Poland's energy policy until 2030 clearly indicates that, in Poland, the sustainable use of renewable energy sources will be supported, and the most energy-efficient solutions will be preferred. In relation to biofuels, it means primarily supporting the production of second-generation biofuels [MG 2009].

The challenges for the future development of the liquid biofuels sector will mean a complicated legal situation, changes in regulations (especially from the perspective of producers), economic determinants (the profitability of production, the impact on agricultural markets) as well as a discussion on its impact on the climate, which has been going on for years, especially in the context of sustainable development. It is worth emphasizing, once again, that the literature indicates that instability of the law (legal regulations) may be a factor which harms business and discourages from investing, including the renewable energy sector [Guaita-Pradas, Blasco-Ruiz 2020, Mirowski, Sornek 2015]. Policy (including energy policy) may play a significant role in promoting the use of the renewable energy sector [Rokicki et al. 2021b]. The crucial role for policy seems to be, however, to create the stable legal circumstances to let the sector develop in the long term.

CONCLUSIONS

The number of legal regulations for the liquid biofuel sector in Poland is high, which is partially reflected in the model obtained. The impact of some of the analyzed legal acts on the price level on the Polish biodiesel market was statistically significant. The key factors for the evolution of biofuel prices were Directive 2003/30 of the European Parliament and of the Council on the promotion of the use of biofuels or other renewable fuels for transport, the Act of 2008 on excise duty, the Act of 2015 on renewable energy sources, as well as the Act of 2014 amending the Act on liquid biocomponents and biofuels and some other acts. Apart from these legal acts, changes in the USD/PLN exchange rate and changes in crude oil prices significantly impacted biodiesel prices. Since the beginning of the biofuel sector in Poland, which can be considered the year 2003, a lot has changed in legal regulations. Poland has become a member of the European Union; biofuel technology has developed significantly and the share of biofuel in total fuel consumption has significantly increased. A positive element seems to be the fact that biofuel policy is based on a long-term strategy thoroughly prepared by European Union institutions that pursue a sustainable policy for sustainable development. On the other hand, however, frequent changes to the regulations are indicated. Therefore, continuous research on the relationship between changes in regulations and the state of development of the biofuels market seems to be important and necessary.

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DETERMINANTY CEN BIOPALIW PŁYNNYCH W POLSCE

Słowa kluczowe: biopaliwa, polityka, ceny, kurs walutowy, ropa naftowa, regulacje prawne, Polska, odnawialne źródła energii

ABSTRAKT

Celem badań było określenie wpływu regulacji prawnych obowiązujących na rynku biopaliw i biokomponentów ciekłych w Polsce na ceny estrów metyloowych kwasów tłuszczowych (tzw. biodiesla lub biopaliwa BIO100). Wskazano na znaczenie regulacji prawnych w kształtowaniu cen biodiesla w Polsce na podstawie danych empirycznych z lat 2008-2016 (najnowsze dostępne dane). Dodatkowym celem była ocena regulacji prawnych jako czynników kształtujących ceny ekodiesla (diesla z domieszką biodiesla) w Polsce, na podstawie danych empirycznych z okresu 2004-2021. Wyróżniono zmienne instytucjonalno-prawne oraz ekonomiczne, zakładając, że rynek biopaliw płynnych, podobnie jak wiele innych rynków, jest silnie regulowany, a uwzględnienie aktów prawnych jest kluczowe dla jego funkcjonowania. Zastosowano analizę regresji wielokrotnej. Źródłem danych były oficjalnie dostępne bazy danych (dane PKN Orlen, FRED Economic Research Data oraz notowania kursów USD/PLN), natomiast źródłami aktów prawnych były Dziennik Ustaw RP i Dziennik Urzędowy Unii Europejskiej. Uzyskane wyniki wskazują, że ceny biopaliw (tutaj: biodiesla) w Polsce zależą zarówno od czynników ekonomicznych (kurs USD/PLN oraz ceny ropy naftowej), jak i od niektórych regulacji prawnych, w tym krajowych i unijnych. Wykazano znaczenie unijnej dyrektywy 2003/30 w sprawie promowania stosowania biopaliw lub innych paliw odnawialnych w transporcie oraz ustaw: o odnawialnych źródłach energii (2015 rok), o zmianie ustawy o biokomponentach ciekłych i biopaliwach (2014 rok) i o podatku akcyzowym (2008 rok).

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