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The Impact of COVID-19 Pandemic on Agri-Food and Biofuel Sector in the EU

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Abstract: *Biofuels refer to sustainable alternatives derived from biomass to replace fossil fuels, contributing significantly to reducing carbon dioxide emissions. However, the biofuel and food price debate is a long-standing, controversial one, with wide-ranging views, both in the public debate and in the scientific literature. The major problem of preferred feedstocks for the 1st generation biofuel production is that these feedstocks are also used for food and feed production. Moreover, there is persistent concern that biofuels compete with food production and that increasing biofuels prices lead to an increase in agricultural commodity prices. The lockdowns as a consequence of the COVID-19 pandemic hit the biofuel sector and reduced demand for all transport modes as energy demand around the world has decreased by 18 – 25%. Lower demand for biofuels affects the demand for its feedstocks, maize and oilseeds, which, in turn, affect the markets for other crops and animal products. The paper intends to provide an expert perspective on the issue of the consequences of the COVID-19 pandemic on agri-food and biofuel sector in the EU –the world leader in the production and use of biodiesel for transport. More specifically, the linkages between the first-generation biofuels and agri-food commodity prices will be examined using co-integration analysis and VECM-type models.*

1. INTRODUCTION

Interest in biofuels has increased over the past decade with the development of climate change mitigation policies and strategies to reduce greenhouse gas emissions from the transportation sector. Antar et al. (2021) argue that biofuels are among the most effective strategies for reducing greenhouse gas emissions and global warming while meeting energy requirements. More than 66% of the world's renewable energy comes from biofuels and waste, 59% is solid biofuels, while liquid biofuels represent 4.9% and biogas 1.7% (International Energy Agency (IEA), 2020). Solomon (2010) also notes that biofuels can play a key role in solving these problems in many nations, as long as the biomass sources are grown, converted, and used sustainably. Takeuchi et al. (2018) state that one of the reasons for the worldwide introduction of biofuels are their properties: 1) Carbon neutral character (The Kyoto Protocol considers biofuels to be carbon neutral because the CO_2 emissions for the combustion of biofuels are offset by the absorbed CO_2 during the growth of plants intended for the production of biofuels); 2) Renewable energy; 3) Prevention of air pollution; 4) Contribution to energy security; 5) Contribution to the development of agriculture and the countryside (increasing agricultural profit, creating job opportunities in the agricultural sector, etc.).

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However, despite the mentioned benefits of biofuels, Cavelius et al. (2023) point out that during the global food demand crisis in 2007/2008, crops used for biofuel production became more important to be used as food, giving rise to the "food versus fuel" debate that continues to these days. In addition, the increased demand for crops for fuel production led to an increase in the market price of these foods. At present, about 60% of ethanol is produced from maize, 25% from sugarcane, 2% from molasses, 3% from wheat, and the remainder from other grains, cassava or sugar beets and about 75% of biodiesel is based on vegetable oils (20% rapeseed oil, 25% soybean oil, and 30% palm oil) or used cooking oils (20%) (OECD-FAO, 2021). Sobczak and Gołębiewski (2022) mention that even though the issue is not new, it is still highly important to take into consideration the expansion of energy crops, as well as national, European and world energy policy, particularly since, the use of plant products for the production of biofuels affects the condition of the food market. According to Lee and Ofori-Boateng (2013), the production of biofuels has various impacts on certain activities such as food production, water quality, biodiversity, etc., therefore, the choice of raw materials, plantation and harvesting technologies, production process designs, product delivery methods, etc., largely determine their sustainability. Thus, sustainability assurance is a key issue in trying to ensure that biofuels are as sustainable as possible and to avoid as far as is possible unintended negative effects of their adoption (IEA Bioenergy, 2008).

Recently, the COVID-19 pandemic and the conflict between Russia and Ukraine have affected the global economy, including the energy sector. Bergquist and Stengaard (2020) noted that Coronavirus Disease 2019 (Covid-19) was found as atypical pneumonia in central China in December 2019, growing to a million confirmed cases worldwide in just 10 weeks. This led the World Health Organization (WHO) to characterize the outbreak as a pandemic on 11 March 2020 (WHO, 2020). Ioannidis (2022) specifies that there are no widely accepted, quantitative definitions for the end of a pandemic such as COVID-19. He defines that the end of the pandemic due to a new virus and the transition to endemicity may be explained by a high proportion of the global population having some immunity from natural infection or vaccination. In addition, other factors might be considered such as diminished death toll, diminished pressure on health systems, reduced actual and perceived personal risk, elimination of restrictive measures and decreased public attention. The pandemic had both direct and indirect consequences on the bioenergy and bio-based product sectors, which were closely related to the fossil fuel industry and the market disruption brought on by COVID-19, as claimed by Galanakis et al. (2022). Zakeri et al. (2022) stressed that the COVID-19 pandemic has caused huge fluctuations in energy demand, oil price volatility, disruption of energy supply chains and hindered energy investment. According to Zhang et al. (2021), COVID-19 has created chaos in the energy system; from the micro perspective, the pandemic has diminished both energy prices and stock values of energy companies, resulting in huge fluctuation of the energy market and from the macro perspective, the spill-over effects of energy market volatility have affected both energy exporters and importers. The global economy has been destroyed by COVID-19, which has also seriously harmed the ever-emerging biomass supply chain and caused its sustainability to collapse, thus the pandemic has raised concerns over the sustainability of biomass feedstock (Sajid, 2021). Yaya et al. (2020) and Norouzi et al. (2020) mentioned that the nationwide lockdown policy during the pandemic restricted production, transport and trade both domestically and globally and directly reduced energy demand. Marcuta et al. (2023) clearly stated that, from 2010 to 2022, there was a rise in the production and consumption of biofuels on a global and local level, except for 2020–2021, when declines were seen as a result of the Covid-19 epidemic. Additionally, Elleby et al. (2020) noted that biofuel prices showed a significant drop down in 2020, followed by their main feedstocks, maize and oilseeds.

The paper provides an expert opinion on the issue of the consequences of the COVID-19 pandemic on agri-food and biofuel sector in the EU – the world leader in the production and use of biodiesel for transport. The paper focuses on biofuel-food market interactions, considering that biofuel issues and the use of farm crops in energy generation are highly topical and discussed not only in the agricultural community. Thus, the main objective of the paper is to assess the impact of biofuel production on agriculture, which is a source of biomass for energy purposes, purposefully cultivated or obtained as a by-product or agricultural waste during the COVID-19 pandemic. More specifically, the linkages between biodiesel and agri-food commodity prices (rapeseed) are examined in the case of Germany as the largest producer of biodiesel in the EU. The scientific level of the project will be ensured through a methodological approach designed for solving research issues and using quantitative research methods and techniques based on co-integration analysis and estimation of the Vector error correction model (VECM).

2. DATA AND METHODOLOGY

Europe is one of the largest producers of biodiesel in the world and uses oil crops as a raw material for the production of biodiesel, especially oilseed rape. The paper aims to examine price links between biodiesel prices and rapeseed prices in Germany to investigate the impact of biodiesel production on agriculture during the COVID-19 pandemic. Germany is the largest producer of biodiesel in Europe, followed by France and Spain (European Biodiesel Board, 2023). The paper intends to provide answers to the following questions:

1. Is there a nexus between rapeseed and biodiesel prices during the study period?
2. How do the prices of rapeseed and biodiesel relate to each other over the study period?

The price indices for producer prices of rapeseed in EUR/t and wholesale prices of biodiesel in ct/l excluding VAT were used from UFOP (Union for the Promotion of Oil and Protein Crops, 2020-2023). On January 9, 2020, China's CDC identified a new coronavirus as the cause of the COVID-19 outbreak (European Centre for Disease Prevention and Control, 2023) and on 5 May 2023, the WHO declared that COVID-19 is no longer a PHEIC (Sarker et al., 2023). Therefore, collected data are set up on a weekly basis, covering the period from January 2020 to April 2023. For the estimations, the prices are turned into natural logarithms, which allow the long-run coefficients to be interpreted as long-run price transmission elasticities.

Cointegration approaches have been widely applied to investigate the mechanisms underlying the transmission of agricultural prices. Sirohi et al. (2023) consider that cointegration models assume that variables that are integrated of order one (I(1)) are connected by a long-term (LR) relationship, and the residuals of this relationship are stationary. If time-series variables are cointegrated, then their long-run equilibrium relationship fits into a dynamic specification in the class of error-correction models (ECM), as stated by Jiang et al. (2015). Ivanova and Dospatliev (2023) explain that there are two varieties of Johansen cointegration tests for identifying long-run connections or long-run equilibrium between time series samples with unit roots (i.e. I(1)):

- The trace test:

$$\lambda_{trace} = -2\, lnQ - T \sum_{t=r+1}^{p} \ln(1-\lambda_t) \tag{1}$$

The H_0 hypothesis for the trace test states that there is no cointegration, i.e., $r = 0$. The alternative hypothesis (H_1) states that cointegration exists, i.e., $r > 0$.

- The maximum eigenvalue for testing the existence of a single cointegration vector:

$$\lambda_{max} = -2\ln(Q: r|r+1) = -T\ln(1-\lambda_{r+1}) \tag{2}$$

The H_0 hypothesis states that the number of cointegrating vectors is *r* against the H_1: r + 1 cointegrating vectors.

David et al. (2019) mention that since the test is based on the matrix coefficients β and α that make up the model, it is known that the cointegration process is directly related to the VECM. The long-run equilibrium is connected to the β parameters and the "speed adjustment parameters," or α parameters, explain how quickly the series tends to return to equilibrium following a disturbance.

When a large range of short-term fluctuations occurs, VECM (a constrained VAR model with a co-integration constraint in explanatory variables) will make endogenous variables converge to their long-term co-integration relationship (Zhou & Zou, 2007). According to Martignone et al. (2022), a description of the connections between and among the markets can be obtained through the VECM as well as a framework for evaluating nonlinear adjustment to the long-term equilibrium can be established using the error correction representation. However, Zhou et al. (2023) stress that the stationarity test must be performed before computing the VECM model in order to make sure that there won't be two erroneous results of a negative model coefficient and pseudo regression in the research. Thus, the augmented Dickey–Fuller (ADF) unit root test is used to determine if each of the logarithmic price series is stationary. Onubogu and Dipeolu (2021) report that the co-integration test is conducted if the unit root test verifies that there is a unit root (at level) in the price series and that the price series must be differentiated by the same order in order to achieve stationarity. Tested hypotheses include:

H_0: There is a unit root in the series and H_1: The unit root is absent.

Zhang et al. (2021) define the basic form of the model, VECM (p-1), set by Johansen as follows:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \varepsilon_t \tag{3}$$

Y_t is a *Kx1* vector of variables, A_i is a *KxK* matrix of parameters and ε_t is a *Kx1* vector of disturbance. ε_t has zero mean, covariance matrix $\sum$, and is i.i.d normal over time.

Bentivoglio et al. (2016) emphasize that that the *Π* matrix can be broken down into $\Pi = \alpha\beta'$ when it is not of full rank, with beta representing the matrix that represents the co-integrating relationship, furthermore, the error-correction model (ECM), derived from the co-integrating equations by inserting the lagged error-correction term, reintroduces the long-run information lost through differencing as well the short-run adjustment to long-run equilibrium trends is represented by the error-correction term.

3. RESULTS

3.1. Development Status in the Selected Biodiesel Markets

Overall, global biodiesel production increased by approximately 60% during the period 2016-2021 (Figure 1). A slowdown of 1.2 billion litres was recorded in 2020 compared to 2019 as a consequence of the COVID-19 crisis that hit the biofuel sector and reduced demand for all transport modes. However, global biodiesel production overcame pre-pandemic levels and reached a volume of 60.7 billion litres in 2022. With a biodiesel volume of 17.7 billion litres in 2022, Europe remained the world´s largest producer. The United States produced 14.5 billion litres and in the case of Indonesia, the production of biodiesel was over 9 billion litres in 2022.

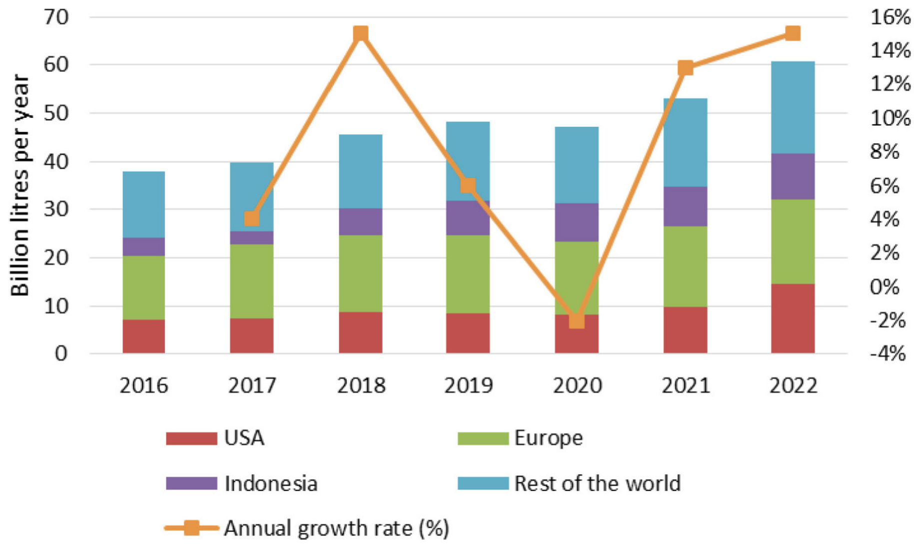

Figure 1. Global biodiesel production by country/region (in billion litres)

Source: International Energy Agency (2021), Own processing

3.2. Empirical Findings

Based on the results, the time series have a unit root and are not stationary. The ADF test indicates that all levels of variables are non-stationary and integrated of the first order I (1) at the 1% significance level. On the contrary, the variables are stationary in the first differences (Table 1). VAR modelling determines the optimal number of lags using the Akaike criterion, Schwarz Bayesian criterion, and Hannan-Quinn criterion. The results indicate that co-integration techniques can be used to investigate the nexus between variables. Therefore, co-integration is examined using the Johansen trace test and the L-max test. According to the findings provided in Table 2, the null hypothesis of no cointegration is rejected, thus the alternative hypothesis ´There is evidence for a cointegrating relationship´ is accepted.

Table 1. ADF test results for prices of biodiesel and rapeseed

Price	Test without constant		Test with constant		Test with constant and trend	
	Level	FD	Level	FD	Level	FD
Biodiesel	0.7845	1.956e-012***	0.5229	3.478e-011***	0.8574	1.5e-010***
Rapeseed	0.7356	5.961e-005***	0.6559	0.00147***	0.9941	0.003867***

Notes: FD: First difference; *** significant at 1% level

Source: Own processing

Table 2. Results of Johansen co-integration test for prices of biodiesel and rapeseed

Variables	L – max test		Trace test	
	r = 0	r = 1	r = 0	r = 1
Biodiesel-Rapeseed	18.966	5.3278**	13.639	5,3278**

Notes: r = 0 – no co-integration relationship;
r = 1 – at most one co-integration relationship;
** significance at 5% level

Source: Own processing

The nature of the long-term nexus between the variables is represented by the cointegration vector β and the coefficient represents the long-run elasticities. The results provided in Table 3 have revealed the cointegration vector as follows: (1.000; -0.87521) implying that a 1% increase in rapeseed prices results in a 0.87521% increase in biodiesel prices. The adjustment coefficient α is statistically significant at the 1% level only in the case of biodiesel prices. Biodiesel prices have revealed negative signs of ECT– indicating a move back towards equilibrium. Besides, the adjustment coefficient α indicates that the response to price changes is rather fast; 45.83% of the disequilibrium inaccuracy has been fixed. In addition, rapeseed prices appear to be weakly exogenous and the findings provide evidence that biodiesel prices adjust to shifts in the price of rapeseed over the examined period. To sum up, rapeseed prices have an impact on biodiesel prices, thus the linkage between the pairs of studied series is one-way during the COVID-19 pandemic. The findings are not surprising given the fact that the production of biodiesel and hydrogenated vegetable oil (HVO) in Germany and Europe depends increasingly on the supply of rapeseed (Biofuels International, 2022). We assume, that the relationship between the rapeseed – biodiesel prices is not simultaneous given that there are other key elements pressuring rapeseed prices in the period under review. As stated by the Council of the European Union (2022), the agri-food sector handled the crisis caused by the disease COVID-19 relatively well, however, in 2021 and the last period inflationary pressures in the area of energy, raw materials, fertilizers (in particular, fertilizer prices increased by 225% from 2020 to March 2022) and freight transport rose sharply. Moreover, the Russian-Ukraine conflict has brought new shocks and uncertainty to world markets, while the EU was particularly exposed to the conflict due to its proximity and trade relations.

Diagnostic tests demonstrate that the ARCH test confirms the null hypothesis of homoscedasticity and the null hypothesis of no autocorrelation is accepted as well. The regression model accounts for roughly 36% of the variance (Table 3).

Table 3. VECM estimation - biodiesel prices and rapeseed prices

	l_biodiesel
Constant	-0.146135**
Cointegration vector β	-0.87521
Adjustment coefficient α	l_biodiesel -0.458257*** l_rapeseed 0.128754
Unadjusted R-squared	0.360109
ARCH*	0.36323
Autocorrelation*	0.549

Notes: ***significance at 1% level, ** significance at 5% level, *p-value

Source: Own processing

4. CONCLUSION

The paper investigated the linkages between biodiesel and rapeseed prices in the case of Germany as the largest producer of biodiesel in the EU during the COVID-19 pandemic. The long-term relationship between variables was confirmed using the Johansen co-integration test. The biodiesel-rapeseed price linkage was not simultaneous, according to the vector error correction model. The model revealed that there was a one-way link indicating that biodiesel prices adjusted to shifts in the price of rapeseed during the COVID-19 crisis. We assume that the price-interconnection of biodiesel and rapeseed prices was not simultaneous since there were other significant factors influencing the agricultural sector in the EU over the review period, e.g. inflationary pressures in the area of energy, raw materials, fertilizers, and freight transport. On the contrary, Sobczak and Gołębiewski (2022) analyzed the volatility and dependence of biodiesel and rapeseed prices during the pre-Covid-19 pandemic (2016-2019) by the vector error correction model and found that biodiesel prices were influenced by the previous week's prices of biofuel and rapeseed, however, the rapeseed prices were influenced by biodiesel prices as well. We posit that crucial elements of the future time perspective, which apply to the studied issue, include considering all aspects of the agricultural process involved in the production of rapeseed (and/or other crops used as feedstock for biofuels), encompassing three pillars of sustainability: environmental, social and economic. These metrics are critical for quantifying not only the benefits but also the drawbacks of producing biodiesel.

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