CHAPTER 10

The Relationship Between Renewable Energy Consumption, Oil Price, Gold Price, Exchange Rate, and Stock Market

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Introduction

Because oil formation takes many years, it is included in the non-renewable (fossil) resources in the classification of energy resources. Petroleum is a very important energy input in terms of the robustness of the economic structures of countries and their growth. Petroleum is an important fossil resource because it has a high share of in the world in terms of energy consumption. In today's age, oil is still a heavily used energy source. The main reason for this is the widespread consumption network. Today, it is used in a very large areas from electricity generation to logistics activities (Gökçe, 2015). Due to the high share of global energy consumption as a result of this intensive

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use of oil, the change in the prices of oil, which is called black gold, affects the economies of the countries. This power of influence is related to the country's dependence on oil and the share of oil in national income. In oil-dependent and oil-importing countries, the level of prices affects various macroeconomic variables such as the balance of payments, employment, national income, inflation, and interest. The most important effect of these price changes for oil-exporting countries is the positive contribution to the exported oil revenues and directly to the national income (Solak, 2012).

The fluctuations in energy prices after the war between Russia and Ukraine turned the eyes on countries with the largest oil reserves in the world. Although energy, which is among the sanctions that come to the agenda in cases of war between countries, political crisis, etc., is an "inviolable" field, shocks in the energy market show that the increase in prices and more importantly, foreign dependence in energy is as important as defense (Karagöl, 2022a). Countries with energy resources, especially oil reserves, will be less affected by possible crises and will leave with less loss from sanctions.

Because few countries own the vast majority of oil reserves within the above-mentioned issues, there is a compulsory dependency on other countries. This dependency can be at a level that will shake the economies of dependent countries in possible crises. For this reason, countries are looking for alternative energy sources in order not to be dependent, and not be weakened by crises and political blackmail. Each country is trying to discover its geographical advantages. More efforts are being made to find natural gas and geothermal deposits, both on land and in the sea, with geophysical-geological models. For example, as a result of the researches carried out in this context in the Eastern Mediterranean, it has been determined that there are two oil reserves of 1.7 billion barrels and natural gas reserves of 3.45 trillion cubic meters. These energy resources in the Eastern Mediterranean are considered to have a strong global impact. However, the inconsistencies of the countries of the region on fair sharing also contain geopolitical risks in the international market of energy resources (Tuna, 2020, 79). Since fossil fuel resources are depleted, the world is now working to include "Renewable Energy" resources in energy input to reduce dependency on these resources. These energy sources are seen as a way out for the future of the world since they are both environmentally friendly and renewable.

This effort shows that renewable energy has increased its share of total energy consumption. According to the Renewable Energy Market Outlook Report for May 2022 and 2023 announced by the International Energy Agency (IEA), problems in logistics activities and supply chain due to the covid-19 pandemic that affected the world, the slowdown in the manufacturing industry, production coming to a halt in some sectors, raw materials despite record-breaking increases in prices and the ongoing challenging process, increases in renewable

Investment capacity reached record levels, increasing by 6 percent in 2021. In addition, it is stated in this report that it will have great potential to reduce dependence on fossil fuels in the short and long term. Another point mentioned in the report is that even if the investment costs of solar and wind energy increase, the increase in other fossil resources will accelerate renewable energy investments. As stated before, the war between Russia and Ukraine harmed energy prices and as a result, a global energy crisis was experienced. These astronomical increases in energy prices have led countries to alternative sources. The most important of these alternative sources is renewable energy (Karagöl, 2022b).

World Oil Reserve by Country

Data on oil production, which is still the most important energy input in the world, is presented in Table 1. OECD countries' oil production of 679,968 Mt in 1971 reached 1279.80159 Mt in 2020. When evaluated for the year 2020, although there is a decrease in production compared to the previous year (2019), it is seen that the highest production (1279.80159 Mt) is realized in OECD countries. Afterward, it is seen in the table that the highest production is realized in the Middle East countries (1278.306073Mt).

Table 1: World crude oil production by region, 1971-2020 (IEA)

Units: Mt

Year	OECD	Middle East	Non-OECD Europe and Eurasia	China	Non-OECD Asia	Non-OECD Americas	Africa
1971	679.968	804.628	395.816	39.41	62.456	229.503	276.755
1972	692.148	902.396	420.226	45.67	75.794	217.9	277.632
1973	695.155	1056.303	449.016	53.61	90.567	234.82	288.934
1974	670.645	1088.157	478.758	64.85	90.738	213.751	266.408
1975	660.155	978.06	511.058	77.06	88.459	178.962	244.406
1976	655.832	1109.941	538.747	87.16	103.79	178.013	291.109
1977	696.502	1113.426	563.73	93.64	116.218	178.117	305.166
1978	748.907	1069.747	587.746	104.05	115.027	179.315	299.513
1979	790.415	1089.885	599.021	106.15	118.512	192.577	328.566
1980	828.702	945.095	621.215	105.946	116.551	184.698	303.767
1981	849.765	813.134	626.369	101.221	119.024	182.24	244.434
1982	890.226	664.099	630.147	102.123	112.044	173.485	232.028
1983	914.57	599.985	633.436	106.068	121.932	171.658	232.618
1984	954.475	586.898	629.75	114.613	136.076	180.969	254.458
1985	967.088	528.365	611.549	124.895	129.84	178.691	263.973
1986	955.488	618.213	630.335	130.688	139.381	185.48	261.121
1987	961.835	638.89	638.817	134.14	136.142	179.006	262.39
1988	954.461	754.695	638.644	137.046	138.781	188.873	275.361
1989	917.722	817.571	621.129	137.641	149.003	189.18	293.491
1990	916.4548	844.744	589.763	138.306	159.216	206.163	315.738
1991	935.6177	841.098	535.31	140.992	168.087	220.08	329.282
1992	950.8505	931.507	460.416	142.097	164.94	226.216	332.623

1993	958.3336	984.438	411.595	145.174	166.325	236.773	330.49
1994	993.5991	989.841	373.358	146.082	177.935	250.533	332.433
1995	1011.061	999.524	363.004	150.044	183.515	268.778	340.684
1996	1040.041	1003.44	365.805	157.334	182.895	297.76	359.047
1997	1053.675	1048.554	368.995	160.741	183.122	312.756	374.638
1998	1055.363	1104.183	370.45	161.203	183.66	315.73	374.934
1999	1032.477	1071.012	378.277	160.169	183.029	310.606	367.185
2000	1044.497	1138.255	401.253	163.078	179.058	324.684	379.344
2001	1036.028	1114.641	431.48	164.056	178.418	335.669	382.749
2002	1038.214	1045.791	472.974	167.145	178.69	324.696	382.529
2003	1030.508	1129.619	519.596	169.655	176.888	319.681	415.893
2004	1008.695	1196.808	563.838	175.941	180.498	339.713	452.797
2005	957.336	1238.734	581.29	181.426	180.517	353.7	474.09
2006	940.5334	1249.66	603.396	184.853	177.613	357.36	486.333
2007	924.554	1229.673	626.995	186.421	172.8	350.155	498.543
2008	891.4259	1272.917	631.172	190.559	174.288	360.105	500.035
2009	896.0329	1181.473	646.326	189.616	172.122	349.572	482.312
2010	901.0986	1210.934	662.719	203.156	175.2	353.234	497.082
2011	907.956	1317.454	666.717	203.032	170.515	354.385	421.261
2012	954.7448	1323.093	670.066	207.642	172.859	348.282	452.684
2013	1009.583	1314.265	676.393	210.098	166.464	346.579	416.451
2014	1093.76	1321.233	678.1488	211.622	165.744	354.352	396.226
2015	1140.436	1372.02	683.5501	214.756	169.134	352.301	392.383
2016	1106.447	1501.856	693.7275	199.888	168.535	339.085	367.859
2017	1141.894	1459.534	697.3484	191.7257	163.0546	323.8025	386.5491
2018	1248.25	1473.603	710.4247	189.5618	156.5552	291.6974	393.5521
2019	1320.077	1395.174	714.9597	191.2754	150.9715	275.8916	402.7978
2020	1279.802	1278.306	657.4207	195.0305	141.4422	259.8376	329.4168

The table above shows the regional crude oil production amount. On the other hand, in Table 2, the countries that produce the most crude oil on a country basis, as well as the countries with the most reserves, are presented. The United States takes the first place in the table with a 17% share and a production of 706 Mt. Global crude oil production was 4141 Mt.

Table 2: Crude oil production 2020 (IEA)

Producers	Mt.	% of the world's total
United States	706	17.0
Russian Federation	512	12.4
Saudi Arabia	511	12.3
Canada	255	6.2
Iraq	201	4.9
people's Rep. Ugh China	195	4.7
United Arab Emirates	174	4.2
Brazil	153	3.7
Kuwait	131	3.2
Islamic Rep. of Iran	130	3.1
Rest of the World	1173	28.3
World	4141	100.0

Renewable Energy Production and Consumption

Since the major countries of the world have a large proportion of crude oil reserves, countries that do not have reserves have a higher risk of reaching this important energy input. The countries that will be most affected by the price fluctuations in any crisis in the world will be the countries mentioned. The worldwide Covid-19 epidemic, the supply problem in energy resources, and subsequent Russia's occupation of Ukraine and Russia's interruption of the natural gas flow caused an increase in the price of fossil energy resources. These price fluctuations have been the motivating force that directs countries to renewable energy sources. With the increase in the share of renewable energy resources in total energy resources, there may be a decrease in the dependence on crude oil, which is a fossil fuel type.

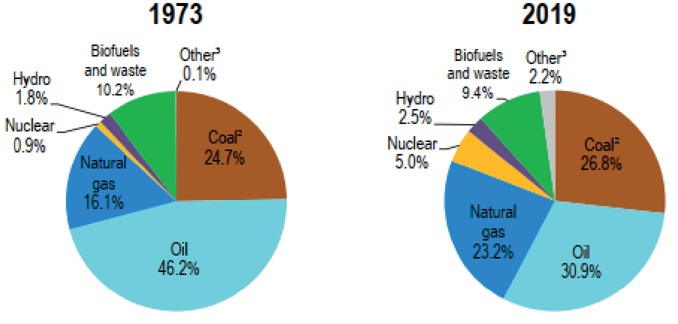

Figure 1: Share of world total energy supply by source, 1973 and 2019 (IEA)

As can be seen in the graphs in Figure 1, while 46.2% of the oil was used as an energy source in 1973, this usage decreased to 30.9% in 2019. This situation shows that the global demand for energy needs has shifted to Natural Gas, nuclear energy, and renewable energy. In other words, we can see statistically that the share of oil in the total energy resource has decreased. The percentage share in these graphs will likely increase in favor of renewable energy sources in the coming years. The actions of international agencies, the work of non-governmental organizations, the R&D investments of companies, the increase in loans given by banks to renewable energy investments, and most importantly, the changes in the current laws of the states and the importance they give will change the ratio of the shares in the charts. Considering that fossil energy sources will run out one day, there will be a compulsory transition to alternative energy sources.

Literature Review

In the literature review, studies in which the VAR model and Granger causality tests were performed were examined. Studies in different disciplines are explained under the title of the literature review.

Dungey and Pagan (2000) developed an 11-variable structural VAR model for the Australian economy over the period 1980 to 1998. The model includes an overseas sector that differentiates between commodity and asset markets to counteract the effects of shocks from all sources. What sets this work apart from its predecessors is the inclusion of an overseas sector and asset markets. In general, it is seen in the study that the effect of monetary policy on the economy contributes to stability, although its effects are not great.

Amitava (2001) stated in his study that countries around the world have the idea that economic development will increase by strengthening their telecommunication infrastructure, and that there is usually an assumption that there is a causal relationship between these two. The author analyzed aggregated data at the national level to see if there was any empirical evidence to support this assumption. He applied the Granger test for causality using time series data for telecommunications infrastructure and economic activity levels from thirty countries. He noted that the evidence for causality from levels of telecommunications infrastructure to economic activity is stronger than causality in the reverse direction. Moreover, this model seems to apply to both industrialized and developing economies, despite having strong service sectors that are heavily dependent on telecommunications. These findings provided additional insights into the complex relationship between telecommunications and economic activity.

Hoffmann et al. (2005) investigated the relationship between foreign direct investment (FDI) and pollution in 112 countries for 15-28 years using Granger causality tests. The findings can be summarized as follows; In low-income countries, CO_2 levels Granger cause foreign direct investment flows. For middle-income countries, the introverted FDI Granger causes CO_2 emissions. Finally, find Granger causality for high-income countries. It reveals alternative causality relationships between two variables depending on the level of development of the host country.

Narayan and Smyth (2005) examined the relationship between electricity consumption, employment, and real income in Australia within the framework of cointegration and causality. They found that electricity consumption, employment, and real income are cointegrated and cause Granger electricity consumption in employment and real income in the long run, while in the short run there is a weak one-way Granger causality running from income to electricity consumption and from income to employment.

Giordano et al. (2007) examined the effects of fiscal policy on private GDP, inflation, and long-term interest rate in Italy using a structural Vector Autoregression model. For this purpose, a database of quarterly cash data for selected financial variables for the period 1982:1–2004:4 was created, based on the information contained in the quarterly reports of the Italian treasury. The results of the study can be summarized as follows; A shock to government purchases of goods and services has a large and powerful effect on economic activity: an exogenous 1% (in terms of private GDP) shock increases private real GDP by 0.6% after 3 quarters. The response goes to zero after two years, reflecting the low persistence of the shock with a lag. The effects on employment, private consumption, and investment have also been positive. The response to inflation has been positive but small and short-lived. In contrast, public wages combined with purchases in many studies did not have a significant impact on output, while their employment impact turned negative two quarters later. Shocks to net income have negligible effects on all variables.

Hurlin and Venet (2008) investigated the causal relationship between financial development and economic growth. *Granger used an innovative* econometric method based on panel testing of the *causality hypothesis*. They applied various tests with a sample of 63 industries and developing countries in the 1960-1995 and 1960-2000 periods. They used three standard indicators of financial development. The results show a strong causal relationship between economic growth to financial development. On the contrary, the causality hypothesis from financial development indicators to economic growth can not be rejected in most cases.

Akinboade and Braimoh (2010) analyzed the issue of international tourism, in which South Africa attaches importance to sustainable economic growth. Although international tourism contributes to the growth of many economies, it is also affected by the growth in many developed countries. Real gross domestic product (GDP), international tourism earnings, real effective exchange rate, and export variables were analyzed in a multivariate vector autoregressive model using annual data covering the years 1980–2005. The main focus of their work is to examine the direction of causality between international tourism earnings and South Africa's long-term economic growth, among other variables, using Granger causality analysis. The obtained result showed a unidirectional causality running from international tourism earnings to real GDP both in the short run and the long run. The error correction mechanism also supported this causality.

Saidi and Ben Mbarek (2016) investigated the causal relationship between nuclear energy consumption, CO2 emissions, renewable energy, and real GDP per capita using dynamic panels for nine developed countries covering the period 1990-2013. Capital and labor are included as additional variables. The results showed that there is a unidirectional causality running from renewable energy consumption to real GDP per capita for the entire panel in the short run. They stated that this would mean that policies aimed at reducing energy consumption may not delay economic growth and income. However, no correlation was found between nuclear energy consumption and real GDP per capita, and a unidirectional causality running from nuclear energy consumption to labor was found. In addition, a bidirectional causality was found between labor and capital and between CO_2 emissions and capital, while there was a unidirectional causality relationship from labor to CO_2 emissions, no causal relationship was found between other variables. It is also concluded that there is bidirectional causality between renewable energy consumption and real GDP per capita in the long run. In addition, the study indicated that there is unidirectional causality from GDP to CO_2 emissions.

Öner (2018) examined the causal relationship between the volatility index (VIX), which is called the fear index, gold, oil, exchange rate and interest. In the study, the author used the working day data of the variables of gold prices, American crude oil (WTI) prices, EUR/USD parity, American treasury 10-year benchmark bond interest rates, and VIX index variables for the period 02 January 2008 – 10 May 2017. In the analysis, the Extended Dickey-Fuller unit root test and Granger causality test were applied and the relationship between the variables was evaluated. According to the results of the study; There is a one-way causality relationship between gold to oil, gold to EUR/USD parity, and gold to US Treasury 10-year benchmark bond interest rates, bidirectional causality relationship between US Treasury 10-year benchmark bond interest rates, and VIX index, and between EUR/USD parity and VIX index.

Avşarlıgil (2020) examined the breaks and changes in the financial markets of COVID-19 in his study. After the cointegration analysis conducted in the pre-epidemic period, the author found that there was no cointegration relationship between the West Texas Crude Oil price (WTI), Bitcoin (BTC), and Euro/Dollar parity (EUR) variables, while there was a significant cointegration between the three variables in the post-epidemic period. stated. That is, the cointegrated movement was seen between BTC, EUR, and WTI, which were not co-integrated between them before the epidemic. In the study, it was seen that the averages changed significantly in terms of the series before and after the epidemic, and the change in WTI was a reason for the change in BTC, as well as a change in the price of WTI in the change in EUR. In addition, as a result of the Zivot-Andrews unit root test with a structural break, it was concluded that there was no structural break at the beginning of the covid-19 epidemic for both WTI, BTC, and EUR.

Duță (2022) analyzed the effect of oil price (WTI and Brent) on the price of oil stocks traded on the Bucharest Stock Exchange from December 2011 to December 2021, using the VAR Granger correlation and causality test. Three oil companies (OMV Petrom, Rompetrol Rafinere, and OMV AG) participated in the study and five stock indices, the EUR stock market index (Euro Stoxx 50), the China50 stock market index, and the Russian RTS index, whose economy is heavily dependent on oil and gas exports. As a result of the study, it is stated that the WTI oil price has a one-way effect on the OMV AG price and there is a bidirectional effect between the WTI oil price and the Russian capital market. At the same time, it is seen that the Brent oil price does not affect oil companies and stock indices.

Data and Empirical Findings

In the study, the relationship between crude oil prices and 5 different variables was examined. Monthly data for the period between January 2010 and February 2022 were included in the study.

Table 3: Variables used in the study

NO	VARIABLE	UNIT/CODE	SOURCE
1	Gold	OUNCE	en.investing.com
2	Dollar Index	DXY	en.investing.com
3	S&P 500 Energy	SPNY	en.investing.com
4	DJ Oil & Gas	DJUSEN	en.investing.com
5	Renewable Energy Consumption	BTU	www.eia.gov
6	Crude oil	WTI	en.investing.com

To determine the relationship between the variables used in the study, the stationarity of the series was tested before the model was set up. Extended Dickey-Fuller (ADF) and Phillips – Perron tests were used for stationarity. y_t The following equation is used to test the unit-roots of the series (Günaydin, 2004) :

$$\Delta Y_t = \alpha_0 + \alpha_1 t + \delta Y_{t-1} + \sum_{i=1}^{N} \Psi_i \Delta Y_{t-i} + \in_t \tag{1}$$

first difference operator in the above equation; Δ t is the time trend; $\in_t$ The error term is Y_t the number of lags of the dependent variable determined by the Akaike Information Criterion to remove the series such as public revenue, GNP, interest rate, and the consecutive dependence of the N error terms. In unit root tests, the h_0 hypothesis states that the series is not stationary. During the test, it is desired to reject the h_0 hypothesis. ADF Unit root test is δ based on the estimation of its parameter and the t statistic. If the h_0 hypothesis is δ negative, statistically significant, and different from zero, it is rejected. The ADF test has a problem in itself. It requires the inclusion of additional differences in terms of the test equation. This situation causes a loss in the degrees of freedom and a decrease in the power of the test. One of the other tests, Phillips-Perron (PP), takes into account the existence of unknown forms of autocorrelation and the conditionally varying variance in the error term and relies on equation (1), excluding N=0. This method uses a non-parametric correction for the serial relationship. Then, the statistics are converted to remove the effects of the serial relationship on the asymptotic distribution of the test statistics (Günaydin, 2004).

In the stationarity test of the study, it was seen that the series were stationary without taking logarithms or differences. However, the logarithms of the series were taken, and then their difference was taken, due to the problems experienced during the subsequent assumptions. Stability test results are shown in Table 4 and Table 5. Akaike information criterion, which is frequently used in finance series, was used in the ADF test. In the tables, the range of the 1%, 5%, and 10% critical values of the test statistic is indicated by the symbol (*).

Table 4: ADF Test

NO	Variable	Intercept	Trend and Intercept
1	dlogGold	-12.9290 (0.000)*	-12.8809 (0.000)*
2	dlogDollar Index	-13,3135 (0.000)*	-13.2688 (0.000)*
3	dlogS &P 500Energy	-12.0182 (0.000)*	-11.9755 (0.000)*
4	dlogDJ Oil & Gas	-12.0364 (0.000)*	-11.9940 (0.000)*
5	dlogRenewable Energy Consumption	-3.4536 (0.010)* *	-3.31441 (0.068)* **
6	dlogCrude Oil	-9.4913 (0.000)*	-9.4991 (0.000)*

****1% **5% *** Indicates 10% significance level. Values in parentheses indicate probe values.***

Table 5: PP Test

NO	Variable	Intercept	Trend and Intercept
1	dlogGold	-13.0070 (0.000)*	-12.9560 (0.000)*
2	dlogDollar Index	-12.2904 (0.000)*	-13.2464 (0.000)*
3	dlogS &P 500 Energy	-12.0182 (0.000)*	-11.9755(0.000)*
4	dlogDJ Oil & Gas	-12.0364 (0.000)*	-11.9940 (0.000)*
5	dlogRenewable Energy Consumption	-35,9600 (0.0001)*	-37.5390 (0.0001)*
6	dlogCrude Oil	-10. 2820(0.000)*	-10,3127 (0.000)*

1% **5% *** Indicates 10% significance level.

Bartlett as estimation method in PP Test Kernel and Newey - West Bandwidth are used for bandwidth selection. According to the results of the stationarity tests, in the ADF test and the PP test, it was determined that the series were stationary in level and with a constant - trend. In other words, the null hypothesis h_0 hypothesis "the series has a unit root" was rejected. In the next part of the study, the lag length is determined.

Table 6: VAR Delay Length Selection Criteria

lag	logL	LR	FPE	AIC	SC	HQ
0	1643,364	NA	1. 68e -18	-23.90312	-23.77523*	-23.85115*
1	1693,092	94.37527	1.37e-18*	-24.10353*	-23.20836	-23.73976
2	1716,034	41.53063	1. 66e -18	-23.91291	-22.25044	-23.23732
3	1738,512	38.72109	2.04e-18	-23.71551	-21.28574	-22.72811
4	1762.137	38,62689	2.48e-18	-23.53484	-20,33778	-22.23564
5	1785,300	35.84401	3.06e-18	-23.34745	-19.38309	-21.73643
6	1826.745	60.50303*	2. 93e -18	-23.42693	-18,69528	-21.50410
7	1847.071	27.89332	3. 87e -18	-23.19812	-17.69918	-20.96348
8	1876,711	38,07799	4.54e-18	-23.10528	-16.83904	-20.55883

Table 6 was created to determine the VAR lag length. To determine the lag length in the table, the lag where the (*) sign is added is selected. It is seen in the table that there is an even distribution. In these cases, it is seen that the lag for which the AIC criterion is marked is taken into account in the literature. In this case, 1 delay is passed and the var model is created.

Table 7: VAR model

	DLOGGOLD	DLOG DOLARENDEX	DLOG CRUDE OIL	DLOGOILGAS	DLOGSP500	DLOG RENEWABLE
DLOGGOLD (-1)	-0.090540 (0.09122) [-0.99250]	0.060048 (0.04058) [1.47983]	0.077827 (0.23382) [0.33284]	-0.131299 (0.16012) [-0.82002]	-0.127672 (0.15718) [-0.81228]	-0.109896 (0.12082) [-0.90956]
DLOGDOLARENDEX (-1)	-0.201446 (0.21460) [-0.93871]	-0.025455 (0.09546) [-0.26667]	0.736471 (0.55006) [1.33890]	0.046657 (0.37667) [0.12387]	0.040370 (0.36975) [0.10918]	0.483730 (0.28423) [1.70190]
DLOGHAMPETROL (-1)	-0.015720 (0.04338) [-0.36243]	-0.012920 (0.01929) [-0.66966]	-0.125266 (0.11118) [-1.12671]	-0.079212 (0.07613) [-1.04045]	-0.082057 (0.07473) [-1,09798]	-0.035352 (0.05745) [-0.61536]
DLOGOILGAS (-1)	-2.156835 (1.07362) [-2.00894]	-0.667139 (0.47756) [-1.39699]	5.828560 (2.75187) [2.11804]	0.205761 (1.88442) [0.10919]	0.128172 (1,84981) [0.06929]	-0.026105 (1.42197) [-0.01836]
DLOGSP500 (-1)	2.167631 (1.08553) [1.99684]	0.727794 (0.48286) [1.50727]	-5.245826 (2.78241) [-1.88536]	-0.125513 (1.90533) [-0.06587]	-0.043062 (1,87034) [-0.02302]	0.266399 (1.43775) [0.18529]
DLOGREENABLE (-1)	0.021156 (0.06042) [0.35017]	-0.049646 (0.02687) [-1,84742]	0.135896 (0.15485) [0.87757]	0.095109 (0.10604) [0.89691]	0.11043 (0.10409) [0.97069]	-0.220409 (0.08002) [-2.75449]
C	0.003366 (0.00389) [0.86549]	0.000939 (0.00173) [0.54308]	0.001176 (0.00997) [0.11797]	0.001499 (0.00683) [0.21959]	0.001803 (0.00670) [0.26903]	0.003850 (0.00515) [0.74751]

In the created VAR model, it is necessary to test whether the process is stationary, in other words, whether it contains a unit root. The stationarity of the model is related to the eigenvalues of the coefficient matrix (Hendry and Juselius, 2001) :

$$\begin{pmatrix} x_t \\ x_{t-1} \end{pmatrix} = \begin{pmatrix} \Pi_1 & \Pi_2 \\ I_p & 0 \end{pmatrix} \begin{pmatrix} x_{t-1} \\ x_{t-2} \end{pmatrix} + \begin{pmatrix} \epsilon_t \\ 0 \end{pmatrix} \tag{2}$$

eigenvalues of the complementary matrix are inside the unit circle, $\{x_t\}$ is stationary;

all if the eigenvalues are inside or above the unit circle, $\{x_t\}$ is not stationary;

eigenvalues is outside the unit circle, $\{x_t\}$ is expanding.

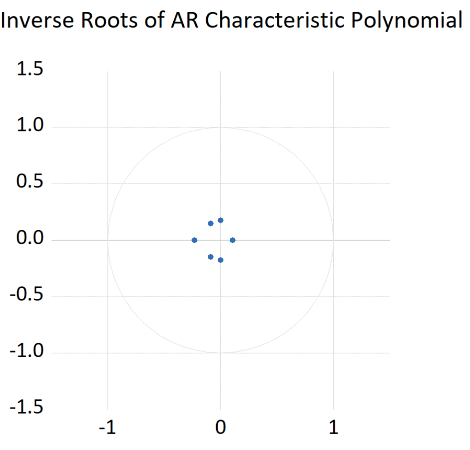

Figure 2: Unit Circle Position of the Inverse Roots of the AR Characteristic Polynomial

Unit Circle Position of the Inverse Roots of the AR Characteristic Polynomial is examined in figure 2. As seen in the figure, all the eigenvalues of the coefficient matrix are inside the unit circle. This shows that our VAR model is stationary.

Table 8: Unit Roots of the Coefficient Matrix and Their Positions in the Unit Circle

root	modulus
-0.231652	0.231652
-0. 000349 - 0.176891i	0.176892
-0.000349 + 0.176891i	0.176892
-0. 087089 - 0.149731i	0.173217
-0.087089 + 0.149731i	0.173217
0.107557	0.107557

The positions of the unit-roots on the unit circle, which are examined graphically in Figure 2, are shown in Table 8. Since all of the values are less than 1, there is no unit root, so the model is stable. The LM test tested whether the

model showed autocorrelation. In the LM test, the null hypothesis of Ho is that there is no autocorrelation. To accept the H0 hypothesis, p>0.05 should be. As can be seen in Table 9, the hypothesis is accepted since the p-value is >0.05 (probe: 0.4002). That is, there is no autocorrelation in our model.

Table 9: Autocorrelation LM test

lag	LRE* stat	df	prob .	Rao F-stat	df	**prob .**
1	37.51370	36	0.3996	1.044964	(36, 556.1)	**0.4002**

Impulse-Response Function Chart Results

Response functions were used to monitor the response of the related variables to a standard deviation (SD) shock given to the Gold, Dollar Index, S&P 500 Energy, DJ Oil & Gas, Renewable Energy Consumption, and Crude Oil variables. The impulse-response functions in the six-variable VAR model are shown graphically in Figure 3 and Figure 4, considering 10 periods.

The 1 SD shock applied to the gold variable, the gold variable responds as a decrease after a rapid increase for the 1st period, and it is seen that the effect disappears by being reset in the 3rd period. Gold can also be affected by its own lagged values and shocks. Despite the 1 SD shock applied to the dollar index, it is observed that the gold variable does not provide a significant response to be taken into account. Likewise, despite the shock applied to the crude oil and gas variables, it was observed that the gold variable did not give a response to be taken into account. In the face of the shock applied to the S&P 500 Energy variable, the response of the gold variable was a small increase until the 2nd Period and disappeared by zeroing in the 3rd Period. Despite the 1 SD shock applied to the renewable variable, the gold variable does not give a significant response. Despite the shock applied to gold, the dollar index showed an opposite movement in the 1st period, while after a small increase in the 2nd period, the 3rd period was reset and lost its effect. Despite the shock applied to the dollar index, the dollar index responded by resetting in the 3rd period after a rapid rise in the 1st period. Despite the shock applied to the Crude Oil, DJ Oil & Gas, S&P 500 Energy, and Renewable Energy Consumption variables, the dollar index gave fluctuating responses, but it lost its effect by zeroing after the 3rd Period. Despite the shock applied to crude oil, DJ Oil & Gas variable and S & P 500 Energy index first increased rapidly, then decreased rapidly, and the effect disappeared after the 3rd period. It is seen in the graph that the response to the 1 SD shock applied to the DJ Oil & Gas index first increases, then decreases, and after the 3rd week, the response decreases and becomes zero. In general, it is seen in the graphs (figure 3, figure 4) that the other variables do not give strong answers despite the shocks applied to the variables in the impulse-response functions.

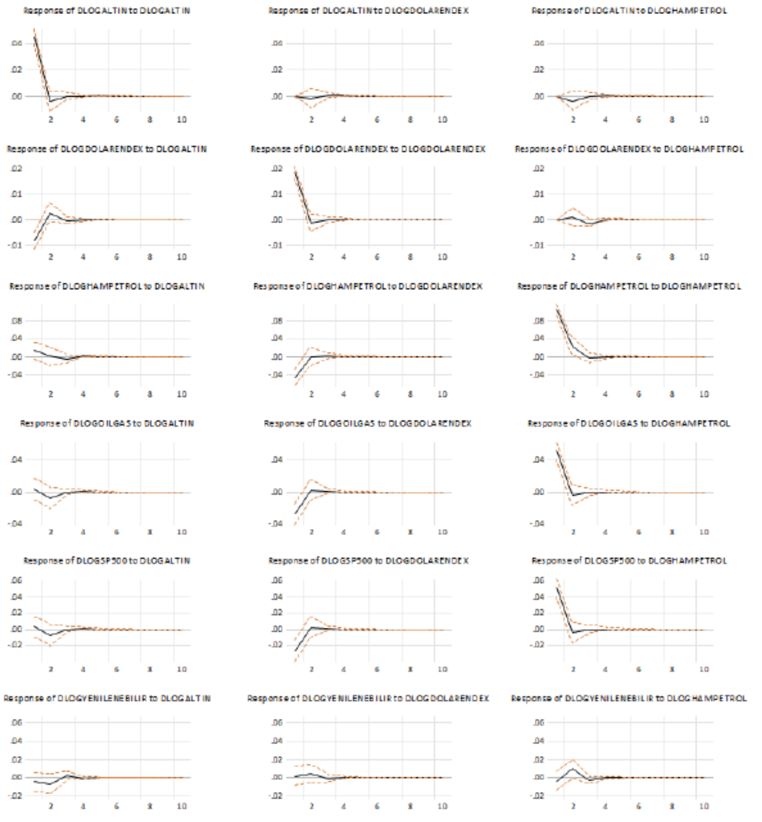

Figure 3: Impulse-Response Graphs

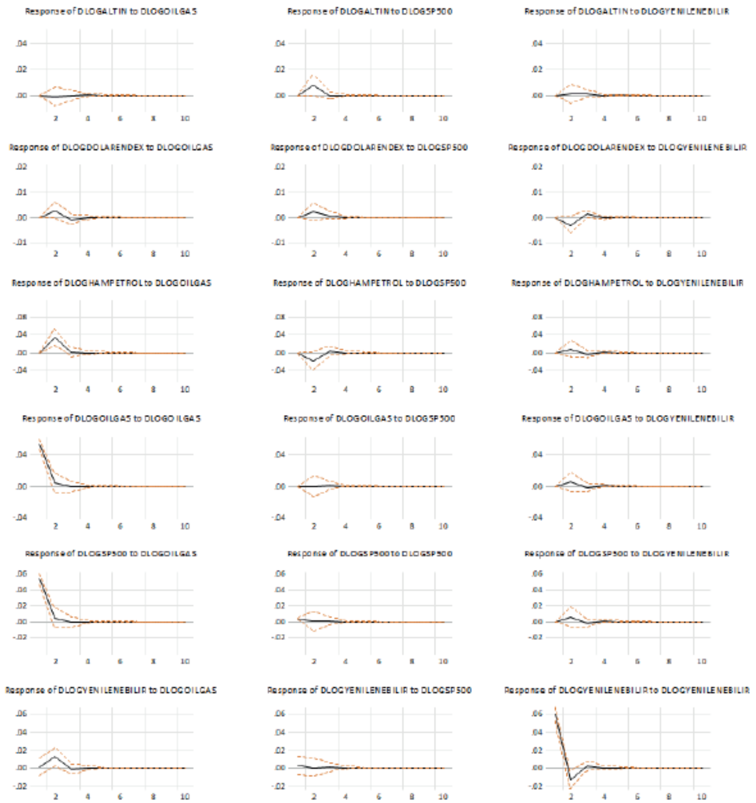

Figure 4: Impulse-Response Graphs (Continued)

Variance Decomposition Results

Variance decompositions offer different methods to observe the movements of the created VAR model in detail. In the model created, the rate of movements in the dependent variables gives shocks to other variables, depending on the shocks of the same variable. For example, a shock applied to variable X will directly affect this variable x, but the important point here is that the applied shock will be transferred to all other variables present in the model structure. Variance decompositions are to measure how much of the estimation error variance before i step of a certain variable is explained by the innovations in the explanatory variable for i=1,2,3 (Sarıkovanlık et al., 2020).

Table 10: Variance Decomposition of DLOGALTIN

period	SE	DLOGGOLD	DLOG-DOLAREN-DEX	DLOGHAM-PETROL	DLOGOILGAS	DLOGSP500	DLOGRenewable
1	0.045858	100,000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.046912	96.33857	0.156810	0.695031	0.041605	2.693902	0.074082
3	0.046926	96.28153	0.163363	0.704057	0.044286	2.694636	0.112131
4	0.046927	96.27579	0.163428	0.705076	0.044830	2.694506	0.116370
5	0.046927	96.27547	0.163447	0.705160	0.044855	2.694496	0.116576
6	0.046927	96.27546	0.163448	0.705160	0.044855	2.694497	0.116582
7	0.046927	96.27546	0.163448	0.705160	0.044855	2.694497	0.116582
8	0.046927	96.27546	0.163448	0.705160	0.044855	2.694497	0.116582
9	0.046927	96.27546	0.163448	0.705160	0.044855	2.694497	0.116582
10	0.046927	96.27546	0.163448	0.705160	0.044855	2.694497	0.116582

In Table 10, the 10-period variance decomposition results of the gold variable are presented. According to the results, a significant part (96.2%) of the error variance in the gold variable is explained by itself, while the remaining approximately 3.75% is explained by other variables.

Table 11: Variance Decomposition of DLOGDOLARENDEX

period	SE	DLOGGOLD	DLOG-DOLAREN-DEX	DLOGHAM-PETROL	DLOGOIL-GAS	DLOGSP500	DLOGRenew-able
1	0.020398	15.96011	84.03989	0.000000	0.000000	0.000000	0.000000
2	0.021171	16,49866	78.30410	0.256551	1.630989	1.306543	2.003158
3	0.021293	16.33132	77,41575	0.699078	1.746561	1.444922	2.362369
4	0.021295	16,33357	77,40469	0.701282	1.746250	1.444783	2.369430
5	0.021295	16,33412	77.40401	0.701294	1.746278	1.444821	2.369476
6	0.021295	16,33414	77,40398	0.701296	1.746277	1.444830	2.369476
7	0.021295	16,33414	77,40398	0.701296	1.746277	1.444830	2.369476
8	0.021295	16,33414	77,40398	0.701296	1.746277	1.444830	2.369476
9	0.021295	16,33414	77,40398	0.701296	1.746277	1.444830	2.369476
10	0.021295	16,33414	77,40398	0.701296	1.746277	1.444830	2.369476

Table 11 shows the variance decomposition results of the dollar index. As can be seen from the table, 10-period variance decomposition has been made and approximately 77.40% of the dollar index is explained by itself. Other variables explain approximately 22.6%.

Table 12: Variance Decomposition of DLOGHAMPETROL

period	SE	DLOGGOLD	DLOGDOLAR ENDEX	DLOGHAM PETROL	DLOG OILGAS	DLOGSP500	DLOGRenewable
1	0.117541	1.372241	16.14276	82.48500	0.000000	0.000000	0.000000
2	0.126555	1.184491	13.92517	74.53778	7.889567	2.042971	0.420022
3	0.126756	1.303545	13.89062	74.35242	7.867854	2.091661	0.493903
4	0.126775	1.306085	13.88648	74,33920	7.878453	2.091223	0.498560
5	0.126775	1.306100	13.88640	74,33910	7.878424	2.091218	0.498762
6	0.126775	1.306109	13.88640	74,33908	7.878429	2.091221	0.498769
7	0.126775	1.306110	13.88640	74,33907	7.878429	2.091221	0.498769
8	0.126775	1.306110	13.88640	74,33907	7.878429	2.091221	0.498769
9	0.126775	1.306110	13.88640	74,33907	7.878429	2.091221	0.498769
10	0.126775	1.306110	13.88640	74,33907	7.878429	2.091221	0.498769

As seen in Table 12, while the crude oil variable is primarily affected by its own lagged values, it is seen that other variables are not at a significant level. While 74.33% of the error variance in crude oil is explained by itself, 25.67% is explained by other variables. According to the table, there are no significant changes after the 3rd period.

Table 13: Variance Decomposition of DLOGOILGAS

period	SE	DLOG GOLD	DLOGDOLAR ENDEX	DLOGHAM PETROL	DLOG OILGAS	DLOGS P500	DLOG Renewable
1	0.080489	0.154466	11.98858	42.48368	45.37328	0.000000	0.000000
2	0.081336	1.023283	11,82892	41.90198	44,74731	0.000413	0.498087
3	0.081374	1.030305	11,82636	41.87072	44.72134	0.004358	0.546913
4	0.081377	1.033702	11.82595	41,86809	44.71950	0.004392	0.548370
5	0.081377	1.033774	11.82592	41,86807	44,71944	0.004392	0.548400
6	0.081377	1.033775	11.82592	41,86807	44,71944	0.004393	0.548402
7	0.081377	1.033776	11.82592	41,86807	44,71944	0.004393	0.548402
8	0.081377	1.033776	11.82592	41,86807	44,71944	0.004393	0.548402
9	0.081377	1.033776	11.82592	41,86807	44,71944	0.004393	0.548402
10	0.081377	1.033776	11.82592	41,86807	44,71944	0.004393	0.548402

Table 13 shows the 10-period variance decomposition results of the variables. Unlike the previously explained variance decomposition results, 44.71% of the error variance in the DJ Oil & Gas variable is explained by itself, while 41.86 % is explained by the crude oil variable. 11.82% is explained by the dollar index variable. The remaining 1.61% is explained by other variables.

Table 14: Variance Decomposition of DLOGSP500

period	SE	DLOG GOLD	DLOGDOLAR ENDEX	DLOGHAM PETROL	DLOG OILGAS	DLOGS P500	DLOG Renewable
1	0.079011	0.103068	11,85545	42.00332	45,83927	0.198891	0.000000
2	0.079909	0.977055	11,67798	41.39766	45.17012	0.194763	0.582421
3	0.079951	0.986920	11.67527	41.36408	45.13943	0.20221	0.634085
4	0.079954	0.990616	1167479	41.36126	45.13741	0.200240	0.635679
5	0.079955	0.990693	1167477	41.36124	45.13735	0.200240	0.635714
6	0.079955	0.990695	1167477	41.36124	45.13734	0.200241	0.635715
7	0.079955	0.990695	1167477	41.36124	45.13734	0.200241	0.635715
8	0.079955	0.990695	1167477	41.36124	45.13734	0.200241	0.635715
9	0.079955	0.990695	1167477	41.36124	45.13734	0.200241	0.635715
10	0.079955	0.990695	1167477	41.36124	45.13734	0.200241	0.635715

Table 14 shows the 10-period variance decomposition result of the S&P 500 Energy variable. According to the results, very little (0.20%) of the error variance in the S&P 500 Energy variable is explained by itself. 11.67% of the error variance is explained by the dollar index, 41.36 % by the crude oil, and 45.13% by the DJ Oil & Gas variable. Unlike the variance decomposition results of other variables explained earlier, a very small part of the S&P 500 Energy variable is explained by itself, and a large part of the error variance is explained by other variables.

Table 15: Variance Decomposition of DLOGREENABLE

period	SE	DLOG GOLD	DLOGDOLAR ENDEX	DLOGHAM PETROL	DLOG OILGAS	DLOGS P500	DLOG Renewable
1	0.060737	0.569339	0.048368	0.368817	0.037780	0.229916	98,74578
2	0.064714	1.978555	0.405929	2.395042	3.809343	0.204627	91.20650
3	0.064884	2.037751	0.413692	2.602036	3.840405	0.224581	90.88153
4	0.064888	2.044729	0.414255	2.601745	3.842019	0.226188	90.87106
5	0.064889	2.045231	0.414264	2.601798	3.842012	0.226376	90,87032
6	0.064889	2.045245	0.414264	2.601797	3.842014	0.226381	90,87030
7	0.064889	2.045245	0.414264	2.601798	3.842014	0.226381	90,87030
8	0.064889	2.045245	0.414264	2.601798	3.842014	0.226381	90,87030
9	0.064889	2.045245	0.414264	2.601798	3.842014	0.226381	90,87030
10	0.064889	2.045245	0.414264	2.601798	3.842014	0.226381	90,87030

In Table 15, the 10-period variance decomposition results of the renewable variable are given. When the table is examined, a significant part (90.87%) of the error variance in the Renewable Energy Consumption variable is explained by itself, while the remaining 10% is explained by others (Gold, Dollar Index, S&P 500 Energy, DJ Oil & Gas and Crude Oil) variables. is explained.

Granger Causality Test Results

Granger Causality Test was conducted to determine the relationship between the variables. The Granger causality test is a test used to determine the direction of causality in the time-delayed relationship between the variables used in the analysis. According to the Granger (1996) test, if B's prediction is more successful when the past values of A are used than when the past values of A are not used, then A is the Granger cause of B (Sarıkovanlık et al., 2020).

Table 16: Granger Causality Test Results

null Hypothesis :	obs	F - Statistics	prob.
DLOGDOLARENDEX does not Granger Cause DLOGGOLD	144	0.24823	0.6191
DLOGALTIN does not Granger Cause DLOGDOLARENDEX		1.68462	0.1964
DLOGHAMPETROL does not Granger Cause DLOGGOLD	144	0.51710	0.4733
DLOGALTIN does not Granger Cause DLOGHAMPETROL		0.00025	0.9873
DLOGOILGAS does not Granger Cause DLOGGOLD	144	0.35487	0.5523

DLOGALTIN does not Granger Cause DLOGOILGAS		1.12267	0.2912
DLOGSP500 does not Granger Cause DLOGGOLD	144	0.25381	0.6152
DLOGALTIN does not Granger Cause DLOGSP500		1.12113	0.2915
DLOGEDGEABLE does not Granger Cause DLOGGOLD	144	0.12075	0.7287
DLOGALTIN does not Granger Cause DLOGREENABLE		2,56980	0.1112
DLOGHAMPETROL does not Granger Cause DLOGDOLARENDEX	144	0.03720	0.8473
DLOGDOLARENDEX does not Granger Cause DLOGHAMPETROL		0.45225	0.5024
DLOGOILGAS does not Granger Cause DLOGDOLARENDEX	144	1.96887	0.1628
DLOGDOLARENDEX does not Granger Cause DLOGOILGAS		0.53171	0.4671
DLOGSP500 does not Granger Cause DLOGDOLARENDEX	144	2.15935	0.1439
DLOGDOLARENDEX does not Granger Cause DLOGSP500		0.53821	0.4644
DLOGEDGEABLE does not Granger Cause DLOGDOLARENDEX	144	3.60995	0.0595
DLOGDOLARENDEX does not Granger Cause DLOGREENABLE		1.95346	0.1644

DLOGOILGAS does not Granger Cause DLOGHAMPETROL	**144**	**12.7787**	**0.0005**
DLOGHAMPETROL does not Granger Cause DLOGOILGAS		1.21228	0.2728
DLOGSP500 does not Granger Cause DLOGHAMPETROL	**144**	**11.8816**	**0.0007**
DLOGHAMPETROL does not Granger Cause DLOGSP500		1.35794	0.2459
DLOGEDGEABLE does not Granger Cause DLOGHAMPETROL	144	0.53226	0.4669
DLOGHAMPETROL does not Granger Cause DLOGREENABLE		0.76235	0.3841
DLOGSP500 does not Granger Cause DLOGOILGAS	144	0.04617	0.8302
DLOGOILGAS does not Granger Cause DLOGSP500		0.07345	0.7868
DLOGEDGEABLE does not Granger Cause DLOGOILGAS	144	0.92217	0.3385
DLOGOILGAS does not Granger Cause DLOGREENABLE		**5.59014**	**0.0194**
DLOGEDGEABLE does not Granger Cause DLOGSP500	144	1.06708	0.3034
DLOGSP500 does not Granger Cause DLOGREENABLE		**5.70608**	**0.0182**

Granger causality test, variable A is not the granger cause of variable B. The probe must be > 0.05 for the null hypothesis of H_0 to be accepted. Based on the probe values in Table 16, the null hypothesis will either be accepted or rejected. According to the results in Table 16, one-way Granger causality running from the DJ Oil & Gas Index to the crude oil variable was observed. Unidirectional Granger causality running from the S&P 500 Energy index to the crude oil variable was observed. Unidirectional causality was observed from DJ Oil & Gas Index to the Renewable Energy Consumption variable. Unidirectional Granger causality was observed from the S&P 500 Energy index to the Renewable Energy Consumption variable. According to the Granger causality test results; DJ Changes in Oil & Gas index affect crude oil, changes in S&P 500 Energy and DJ Oil & Gas indices affect crude oil variable, while changes in DJ Oil & Gas and S&P 500 Energy Index affect Renewable energy consumption variable.

Conclusion

No matter where you are in the world, energy input is needed to continue the flow of life. With the rapid development of technology, machinery, devices, motors, etc. are as important as the energy sources that will activate them. No matter how powerful a car or aircraft engine is produced, it will not make sense if there is no energy to power these engines. Today, oil is still the most important energy input. Petroleum and its derivatives have the most important share in total energy resources. Since few countries in the world have these important energy reserves, it has caused crises throughout history. The fluctuations in the price of this resource cause disruptions in the economy and financial structure of the most dependent countries. To reduce this dependency, the world states are in search of alternative energy sources. The most important of these alternative sources are renewable energy sources that do not have the risk of extinction, such as fossil sources.

In this study, the relationship between WTI crude oil price and the variables in which it interacts was analyzed. These variables are; Gold, Dollar Index, S&P 500 Energy, DJ Oil & Gas, and Renewable Energy Consumption. Among these variables, it has been examined whether the increase in Renewable Energy Consumption, in particular, affects crude oil prices. In the study, unit root tests of the series were made and the series was made stationary. Afterward, the appropriate number of delays was determined and the VAR model was created. After it was seen that the model met the assumptions, the impulse-response functions of the VAR model were calculated. The results of each variable were interpreted with variance decomposition analysis. The Granger causality test was performed for the status of the relationship between the variables. According to the Granger causality test results; Changes DJ in Oil & Gas index affect crude oil, changes in S&P 500 Energy and DJ Oil & Gas indices affect crude oil variable, while changes in DJ Oil & Gas and S&P 500 Energy Index affect the renewable energy consumption variable. In particular, no granger causality was found between the renewable energy consumption of crude oil and between renewable energy consumption and crude oil prices.

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