

Research on the Granger Causality Experiment of Fukushima Nuclear Wastewater Discharge on Changes in Oil Market Prices

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Abstract. Because of the development of economic globalization and the increasing attention of governments around the world to environmental protection, the connection between the economy and the environment is becoming increasingly closer. Environmental and economic concepts such as the circular economy (CE) and sustainable development strategies have gradually become important theoretical support for government economic development. Therefore, environmental pollution has a more significant impact on the economy. The Japanese government declared on August 24, 2023, that effluent from the Fukushima nuclear power plant would be released into the Pacific Ocean. This decision not only has an impact on marine ecology and the marine environment but also has a certain impact on the world economy. The price changes of oil, a crucial industrial fuel and commodity, can also be used as a proxy for the effects of nuclear-contaminated water outflow on the global economy. To investigate the effects of nuclear polluted wastewater on the global economy, this article will examine variations in the price of crude oil after the nuclear waste from the Fukushima nuclear power plant in Japan was released into the environment.

Keywords: Nuclear wastewater; Granger causality experiment; environmental impact

1. Introduction

The world economy is becoming more interconnected internally as a result of the growth of international commerce. Any significant incident that takes place in a particular nation or area will impact the socioeconomic conditions there, which will then ripple across the global economy and ultimately impact the global economy as a whole. According to a press release issued by the Japanese government on April 13, 2021, the Fukushima Daiichi nuclear power station will be sending 1.25 million tonnes of radioactive wastewater into the Pacific Ocean every two years [1,2]. At a formal conference held on March 3, 2023, Japan declared its intention to complete by spring 2023 the facilities associated with the radioactive effluent discharge from the Fukushima nuclear power plant [3,4]. The first batch of radioactive effluent was formally dumped into the sea on August 24 of the same year. Even though the first batch of radioactive wastewater was released later than anticipated, governments and citizens from several nations nonetheless voiced their objections.

On the one hand, nuclear wastewater can seriously pollute the marine environment and bring significant impacts to the marine ecosystem that cannot be ignored. According to LIU [1] research, nuclear wastewater can cause serious impacts on the marine ecological environment, and the radioactive elements in nuclear wastewater can affect the entire marine ecosystem through the food chain. Meanwhile, according to YANG [3] research, the radioactive elements contained in nuclear wastewater will rapidly spread with ocean currents, causing a wider range of impacts. This radioactive contaminated seawater will reach the western edge of the Pacific and the west coast of North America within two years.

On the other hand, nuclear wastewater can also affect the normal order of human society, especially the order of financial trading markets. Japan's nuclear wastewater discharge may have a direct impact on the demand and productivity of fisheries in other Pacific Rim nations, as well as an indirect effect on the world economy [5,6]. Now, many experts and scholars have conducted extensive research on the impact of this event on the human economic environment [7-10]. Among them, some scholars have analyzed the impact of nuclear wastewater on the cross-sectional behavior of stock

returns and then organized and analyzed the public's views and opinions on this event to obtain public opinion guidance and attitudes [11,12]. Meanwhile, some have also investigated the relationship between socioeconomic status and radiation exposure response through data analysis and modeling [13].

Few academics have, meanwhile, looked at how nuclear wastewater events affect the future market. The oil futures market, which is one of the biggest futures markets in the real world, will examine how price fluctuations in the oil market are affected by the effects of nuclear wastewater on the global economy and determine whether these factors have an effect on changes in oil prices. because of a certain market lag. Therefore, in addition to the research on this data, this paper uses quantitative analysis of OPEC oil price data from August to October and makes predictions about future changes in market prices.

2. Data and Method

2.1. Data sources and significance

Oil - Price data are from OPEC, Tables, 2023, October edition. The tables cover 23 major oil-producing countries and regions. By analyzing the changes in crude oil prices (including futures and spot prices) after Japan's nuclear wastewater discharge [14]. Thus, it can be macroscopically discovered whether nuclear wastewater has a certain impact on changes in oil prices.

2.2. Introduction of research methods

This experimental study will first use a linear regression model to conduct a linear analysis of the changes in oil prices, to understand the changes in oil after nuclear wastewater discharge. Based on this, use the ARMA model to predict future oil prices.

The Granger causality test is one-method to try and investigate the Granger causality between variables. This test strategy was created by Clive W. J. Granger, the 2003 recipient of the Nobel Prize in Economics, to examine the Granger causation between economic variables [15]. It is the variance that is dependent on the historical points when all of the data's best least squares estimate was found. The Granger causality test assumes that the time series of variables y and x contain all of the expected data for each of these variables. The following regression needs to be computed for the test [16,17]:

$$y_t = \sum_{i=1}^q \alpha_i x_{t-i} + \sum_{j=1}^q \beta_j y_{t-j} + u_{1t} \quad (1)$$

$$x_t = \sum_{i=1}^s \gamma_i x_{t-i} + \sum_{j=1}^s \delta_j y_{t-j} + u_{2t} \quad (2)$$

The white noise u_{1t} and u_{2t} are thought to be unrelated. The underlying assumptions of Equation (1) and Equation (2) are that the current value of y is related to both y and its previous value, x. Equation (1) has $\alpha_1 = \alpha_2 = \dots = \alpha_Q = 0$ as its null hypothesis. The null hypothesis H_0 for equation (2) is $\delta_1 = \delta_2 = \dots = \delta_S = 0$.

(1) x and y have a one-way causal relationship, which indicates that x is what causes y to change. If the estimated coefficient of lagged x in equation (1) is not statistically significant overall and the estimated coefficient of lagged y in equation (2) is statistically significant overall, then it is assumed that X is the source of the change in y.

(2) X and Y have a one-method causal relationship, which indicates that X changed as a result of Y. If the estimated coefficient of lagged x in equation (1) is statistically significant overall and the estimated coefficient of lagged y in equation (2) is not, then Y is considered to be the cause of the change in x.

(3) Because there is a one-way causation relationship from x to y and a one-way causal link from y to x, X and Y are mutually causative. There is a bidirectional causal relationship or feedback loop between x and y if the estimated coefficients of lagged x in equation (1) and y in equation (2) are not statistically significant overall.

(4) There is either no relationship at all between x and y, or x and y are independent of one another. If the estimated coefficients of lagged x in equation (1) and y in equation (2) are both statistically significant overall, then there is no causal relationship between x and y.

3. Model description and scenario assumption

3.1. Linear analysis model

Linear analysis can more intuitively display the growth or decline of data. Therefore, in this chapter, linear analysis will first be used to demonstrate the changes in world crude oil prices from 2022 to 2023, thereby more intuitively demonstrating the effect on crude oil prices of the radioactive effluent discharge from Fukushima.

According to the OPEC (2023) report, September 2023 and October 2023. The prices of the world crude oil spot market have been consistently increasing.

Table 1. A selection of crudes and the OPEC Reference Basket, US\$/b.

OPEC Reference Basket (ORB)	Value		Change	
	Aug 23	Sep23	Aug 23/ Sep 23	%
ORB	87.33	94.60	7.27	8.3
Arab Light	89.55	96.51	6.96	7.8
Basrah Medium	85.38	93.14	7.76	9.1
Bonny Light	86.52	95.53	9.01	10.4
Djeno	78.69	86.51	7.82	9.9
Es Sider	86.39	94.31	7.92	9.2
Girassol	89.05	97.46	8.41	9.4
Iran Heavy	87.58	94.63	7.05	8.0
Kuwait Export	88.77	95.70	6.93	7.8
Merey	68.48	75.51	7.03	10.3
Murban	87.24	93.86	6.62	7.6
Rabi Light	85.68	93.50	7.82	9.1
North Sea Dated	86.14	93.96	7.82	9.1
WTI	81.41	89.38	7.97	9.8

According to the data in Table 3, the indices selected by major OPEC showed varying degrees of growth in October 2023 compared to September 2023. Among them, Muban has the smallest growth rate, with a growth rate of 7.6%. Bonny Light has the largest growth rate, with a growth rate of 10.4%. Because WTI, ORB, and North Sea Dated are key parameter indicators. Therefore, a price change chart from September 2022 to October 2023 will be drawn based on the data of these three indicators.

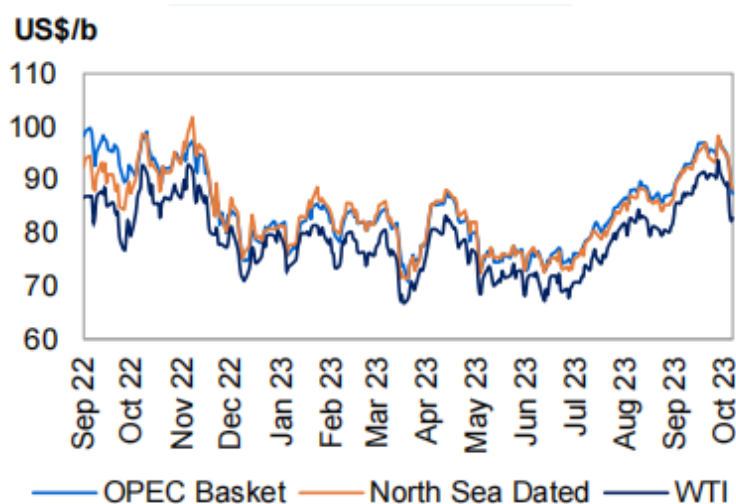


Fig 1. Crude oil price movements [18].

According to the changes in Fig.1, it can be seen that starting from August 2023, the three major crude oil price indices have continued to rise during the same period. It got close to this time's apex in September and October of 2023. Around this time, the Japanese government declared that the Fukushima nuclear power facility had released its first batch of tainted water into the ocean. According to a study by Energies [18], the impact of major international events is one of the reasons that affect the crude oil price index. The Japanese nuclear wastewater discharge incident, as an international event in the first half of 2023, has had a significant international impact and attracted the attention of governments around the world and protests from people around the world [19]. Therefore, it has a significant impact on the oil prices from August 2023 to October 2023.

3.2. Granger causality experiment

This part will examine the relationship between the release of radioactive wastewater from Fukushima in Japan and variations in crude oil prices using the Granger causality test.

The Japanese government not providing a detailed daily average discharge of nuclear wastewater. Therefore, this article will assume that Japan's nuclear wastewater discharge in August was 2000 tons, and in September it was 5778 tons. According to CNN's report, the amount of nuclear wastewater discharged in October was 7810 tons, and the amount in November was 7753 tons. Meanwhile, in this experiment, the crude oil price was selected as the reference price for ORB [20-23].

Firstly, the Granger test requires stationary time series data, otherwise false regression problems may occur. Consequently, in order to determine whether the time series is stationary, the ADF test must be used. If the pairwise time series is non-stationary and satisfies the same order single integer constraint, cointegration testing between the pairwise sequences is necessary. Granger causality testing can only be carried out in the event that there is a cointegration relationship between the sequences. Next, decide on the lag order. It should be mentioned that the Granger causality test can occasionally be sensitive to the lag length selected and that various lag durations can provide radically different test outcomes. For this experiment, the chosen lag order is 1. Because of the lag effect caused by nuclear wastewater discharge into the sea, the lag order is selected as 1. Lastly, the unidirectional or bidirectional nature of the causal relationship between two variables was ascertained using the Granger causality test.

3.2.1. ADF inspection

To determine if the time series is stationary, ADF detection is employed. The outcome of the ADF detection is displayed in Table 2 together with the variables, T-test findings, AIC values, etc. $P < 0.05$ signifies the stationary nature of the sequence. A non-stationary sequence is indicated if $P > 0.05$.

Table 2. The result of ADF detection.

variable	t	P	critical value		
			1%	5%	10%
Nuclear wastewater discharge	-1.319	0.620	-7.355	-4.474	-3.127
Crude oil price	-1.182	0.681	-7.355	-4.474	-3.127

Since there is no indication of significance at the horizontal level, the null hypothesis cannot be rejected based on the significant P-value of 0.620 for the nuclear wastewater outflow variable. The in-question time series is non-stationary. The null hypothesis cannot be rejected since the variable Crude oil price does not demonstrate significance at the horizontal level, according to the significance P-value of 0.681. The concerned time series is non-stationary.

3.2.2. Granger causality

Table 3. Displays the Granger causality experiment's findings.

Paired sample		F	P
Crude oil price	Nuclear wastewater discharge	1.489	0.437
Nuclear wastewater discharge	Crude oil price	2.424	0.363

The Granger causality test findings are shown in Table 3 along with the sample size, paired samples, F-statistic, and significant P-values. Examine the relevance of the F-statistic. The null hypothesis, which explains why one set of time series is not another, is rejected if it is significant ($P < 0.05$); if changes in the right variable may be influenced by changes in the left variable, then a Granger causality link is present. Consequently, the significance P-value is 0.437 based on the variables nuclear wastewater discharge and crude oil price, which does not indicate significance and cannot rule out the null hypothesis. Nuclear wastewater discharge cannot be affected by changes in crude oil prices. The significance P-value for nuclear wastewater discharge and crude oil price is 0.363, which is not significant and cannot be used to reject the null hypothesis. The release of nuclear effluent cannot influence changes in the price.

4. Conclusion

Based on the above experiments, we can conclude that in linear experimental analysis, due to the discharge of nuclear wastewater, the price of oil did indeed increase during the same period. However, in the Granger causality experiment, the results indicate that there is no significant direct relationship between nuclear wastewater discharge and changes in oil prices. On this result, the Granger causality experiment produces more rigorous results, but it still cannot rule out the potential impact of nuclear wastewater discharge on changes in oil prices. Meanwhile, the main reason for this error is that there may be some errors in the sample selection of the data. In this experiment, the selection of oil prices was based on the prices of the OPEC Reference Basket (ORB) from August to December 2023. Therefore, selecting reference prices from different companies or institutions may have different impacts. At the same time, using only the reference oil prices from August to December 2023 may result in insufficient sample size and affect experimental results. Therefore, in subsequent research and experiments, multiple reference price comparisons and increasing sample size methods can be adopted to further study the impact of nuclear wastewater discharge on oil price fluctuations.

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