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Article

Time-varying effects of crude oil price fluctuations on tuna fish prices

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Abstract: This research presents an investigation of the time-varying effects of crude oil on the price of three tuna species, namely skipjack, albacore, and yellow fin. The investigation analyses the impact coefficient of oil price fluctuation on tuna species over time with specific phases related to time points when crude oil prices fall, including December 2008 (due to the impact of the Financial Crisis), February 2016 (due to the impact of the US shale oil and gas revolution), and April 2020 (due to the impact of the global COVID-19). The analysis shows that the price of yellow fin and skipjack shows sensitivity to these phased oil price shocks but stays consistent after recovery. This research finds that the relationship between oil price and tuna price depends on specific phases of oil price fluctuations and that global crude oil price shocks could have immediate and short-term impacts on fish markets, especially during a period of financial crisis.

Keywords: tuna; oil price; commodity; financial crisis; sustainability

1. Introduction

Fish resources are significant to the food security of many nations, and similar to the majority of food systems, fisheries and their supply chains are heavily dependent on fossil fuels [1]. Tuna is one of the oceanic top predators and plays a significant role in marine ecosystems, comprising nearly 20% of the value of capture fisheries. The main commercial species of tuna are the Atlantic bluefin, southern bluefin, albacore, bigeye, yellowfin, and skipjack [2]. These species are the predators of the pelagic ecosystem and are highly migratory, with their distribution covering most of the tropical and temperate areas around the globe. Tuna is one of the most valuable marine resources, and the development of deep freezing storage and enhanced farming techniques has been lucrative for fisheries and resulted in a significant increase in catches [3]. The expenditure on fuel represents a significant component of the operation costs of the fishing fleets, and as a result, the profitability of the fleets is very sensitive to fuel price variations [4]. However, the price of crude oil is subject to constant volatility, and the question of whether the tuna price and the price of crude oil are linked becomes important in the context of fisheries management and planning. Many studies in the literature have investigated the price relationship of crude oil with food commodities, considering linear and non-linear approaches, and reported different findings. This study aims to investigate the time-varying characteristics of the correlation between crude oil price and tuna price, as well as the time-varying impulse responses of the TVP-VAR model for time points, taking into consideration three main oil price shocks in the period under consideration. These time points include December 2008 (due to the impact of the Financial Crisis), February 2016 (due to the impact of the US shale oil and gas revolution), and April 2020 (due to the impact of the global COVID-19).

In the remainder of this paper, the literature review is presented in Section 2, followed by the methodology and approach in Section 3, the results in Section 4, and the conclusions in Section 5.

2. Literature review

In a study by Chen et al. [5], the relationship between oil prices and global food prices is investigated, and they show that the change in each grain price is significantly influenced by the changes in the crude oil price and other grain prices. Zhang et al. [6] investigate the price relationship of three different fuels with five standard food commodities. They do not find a co-integrating relationship between energy and food commodities. Esmaeili and Shokoohi [7] construct a principal component of the prices of different food commodities and investigate the greater causality between the food component and the oil price, among others. They do not find a direct relationship between the oil price and the food price component. Another study [8] finds that an index composed of prices of different commodities (including foods, metals, and other consumption goods) is cointegrated with the oil price. He also finds Granger causality in the direction from oil to the index. Ciaian and Kancs [9] perform cointegration tests between crude oil prices and prices of various food commodities (including potential biofuel commodities and those that cannot be converted into fuel). They find cointegration relationships with oil prices for typical biofuel crops such as corn and soybeans from 1999 on. Hassouneh et al. [10] find long-run equilibrium relationships between the prices of sunflower, biodiesel, and crude oil based on Spanish data. Moreover, they find that energy prices influence sunflower oil prices through short-run price dynamics. Busse et al. [11] investigate the price relationships of diesel, biodiesel, rapeseed, and soy based on German data. They find that the relationships between the different commodity prices were heavily affected by regime switches of support policies. The TVP-VAR method is applied to study the effects of world stock market and oil price shocks on food prices. Their results show that volatility spillovers increase considerably during crises, and shocks to crude oil and stock markets have immediate and short-term impacts on food markets, especially during the financial crisis period [12]. In a study by Balcilar et al. [13], the relationship between the price of oil and agricultural commodities in South Africa is investigated, and they show that the relationship depends on specific phases of the market and that the oil price shall be considered in strategic economic planning.

Analysis of the literature

Some of the studies summarized indicate cointegration and certain causalities between the oil price and the price of food commodities, while others do not. Following a review of the literature, a gap was found in studies investigating the relationship between tuna fish prices and crude oil prices. This is particularly important since fuel is one of the most important drivers in fisheries' operations. In this paper, we aim to investigate the relationship between the price of crude oil and three types of tuna species (albacore, yellowfin, and skipjack) and show the time-varying effects using the time-varying parameter structural vector autoregression (TVP-VAR) method.

3. Methodology

Following the data selection and de-trending of the data, the time-varying parameter structural vector autoregression (TVP-VAR) method is applied. The TVP-VAR method enables us to capture the possible time-varying nature of the underlying structure in the economy in a flexible manner. The data used in this study covers the period between 2000 and 2020, and monthly data on crude oil price (WTI crude oil), skipjack price, and yellowfin price from January 2000 to October 2020 are selected.

3.1. Data selection and data pre-processing

The unit root test was carried out for three time series variables, i.e., crude oil price, skipjack price, and yellowfin price, and descriptive statistics were conducted on them. **Table 1** reports the results of descriptive statistics and the unit root test. According to the ADF test results, except for the yellowfin price, which is stable at the 10% significance level, the time series of other variables are non-stationary. After de-trending using the wavelet analysis, the volatility terms of oil price, skipjack, yellowfin, and Albacore prices are significantly stable at the 1% level, which means that the de-trended variables pass the unit root test and can be used in the empirical analysis using the TVPVAR model.

Table 1. Results of descriptive statistics and unit root tests.

	Mean	**Std.Dev**	**Skewness**	**Kurtosis**	**JB**	**ADF**
Variable (level)						
Crude oil price	62.002	28.309	0.407	2.115	15.004	−2.485
Skipjack price	1282.0	464.72	0.231	2.125	11.160	−2.414
Yellowfin price	1604.5	464.75	0.129	2.142	8.327	−2.592*
Albacore price	2722.3	571.52	0.279	2.761	3.827	−1.795
Variable (volatility term after de-trending by using the wavelet analysis method)						
Crude oil price	0.000	0.182	−0.754	5.803	105.12	−6.122***
Skipjack price	0.000	0.161	−0.190	2.658	2.708	−6.155***
Yellowfin price	0.000	0.118	−0.167	4.224	16.713	−6.933***
Albacore price	0.000	0.104	−0.457	3.520	11.466	−4.451***

Note: 1) JB refers to the Jarque-Bera statistics for testing normality, which is proposed by Jarque and Bera. 2) Test for unit root in level with intercept in the test equation. 3) *, **, *** represents statistical significance at the 10% level, at the 5% level and at the 1% level, respectively. The wavelet analysis method refers to the filtering method of Hodrick and Prescott.

3.2. Analysis of time-varying characteristics

Parameter estimation

Based on the HP filter processing of the original data, the initial values of the parameters are set according to experience, and the MCMC algorithm is used to simulate 20,000 times to obtain effective samples. The parameter estimation results are shown in **Table 2**.

Table 2. Estimation results of selected parameters in the TVP-VAR model.

Parameter	Mean	Std.Dev	95% L[1]	95% U[2]	Geweke[3]	Inef.[4]
$(\Sigma_\beta)_1$	0.0385	0.0099	0.0232	0.0600	0.000	164.67
$(\Sigma_\beta)_2$	0.0429	0.0135	0.0251	0.0748	0.023	134.41
$(\Sigma_a)_1$	0.0584	0.0276	0.0357	0.0997	0.547	61.60
$(\Sigma_a)_2$	0.0611	0.0166	0.0378	0.1026	0.675	81.43
$(\Sigma_h)_1$	0.3642	0.0766	0.2463	0.5406	0.640	130.81
$(\Sigma_h)_2$	0.3729	0.0847	0.2403	0.5840	0.070	105.91

Notes: 1) 95% lower credible interval limit; 2) 95% upper credible interval limit; 3) Geweke convergence diagnostics statistics; 4) Inefficiency.

Table 2 shows the estimated results of selected parameters in the TVP-VAR model of crude oil price, skipjack price, and yellowfin price calculated by the MCMC algorithm, including the posterior mean, posterior standard deviation, 95% confidence interval, Geweke's CD convergence diagnostic value, and invalid influencing factors. In terms of convergence, the Geweke value of each parameter is less than 1.96, that is, the 5% critical value. There is no evidence to prove that all parameters fail the Geweke convergence test, and the Geweke convergence diagnostic test is posteriori distribution convergence. As can be seen from **Table 2**, the values of parameter Inef. are far less than 20,000 samples. Therefore, the number of samples obtained through the above method is sufficient to carry out a posteriori reasoning on the TVP-VAR model.

4. Results

4.1. The time-varying characteristics of the correlation

With the TVP-VAR model, we can get the time-varying characteristics of the correlation between crude oil price and tuna price (skipjack, albacore, and yellowfin price), as shown in **Figure 1**. The time-varying relationship between oil price and tuna price remains below 0. It can be seen from **Figure 1** that the impact of crude oil price fluctuations on tuna price fluctuations is dynamic (left and right subgraphs in the first row of **Figure 1**; the right subgraph in the second row of **Figure 1**). The left subgraph of the first row shows the dynamic influence of oil price fluctuations on Skipjack price fluctuations. During the period of 2000–2011, the impact coefficient of oil price fluctuation on skipjack price fluctuated around 0, and there was no significant correlation between oil price fluctuation and skipjack price fluctuation during this period. After 2011, the impact coefficient of oil price fluctuation on Skipjack price shows a positive upward trend, and there is a positive correlation between them. The right subgraph of the first row shows the dynamic impact of oil price fluctuations on yellowfin price fluctuations. Before 2009, the impact of oil price fluctuation on the yellowfin price was positive; after 2009, oil price fluctuation had a negative impact on the yellowfin price. The right subgraph of the second row shows the dynamic impact of oil price fluctuations on albacore price fluctuations. During the sample period, the impact coefficient of the oil price on albacore varies around 0, and there is no significant correlation between the two. In addition, there is a dynamic correlation between the price fluctuations of different kinds of tuna. There is a significant positive correlation between the skipjack price and the yellowfin price (see the left subgraph in the second line), but there is no significant correlation with the albacore price.

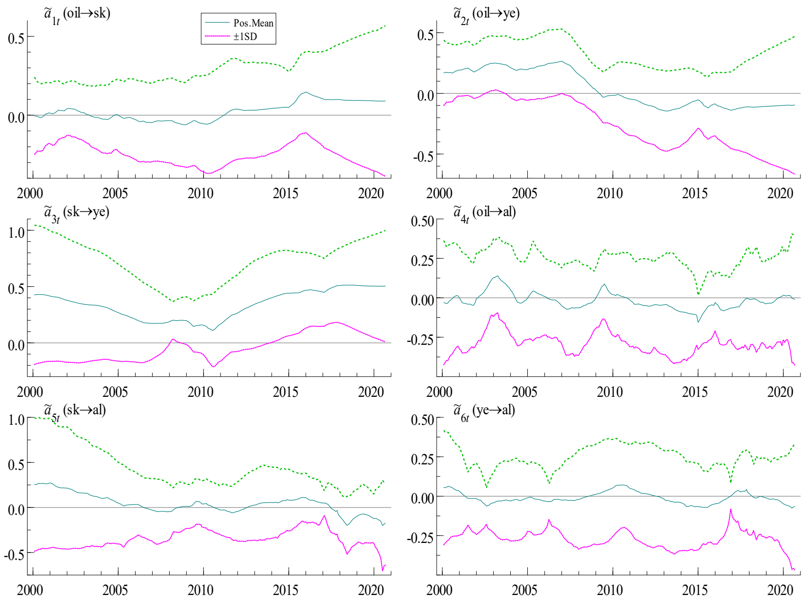

Figure 1. Posterior estimates for simultaneous relations.

4.2. Analysis of time-varying characteristics with time-delay

Figure 2 shows the dynamic characteristics of the changes of oil price and tuna price under different time delay (3, 6 and 12 periods). The four subgraphs in the first row of **Figure 2** show the time-varying response of different time-delay oil price shocks to their own and tuna price changes. It can be seen that the impact of oil price on skipjack price is positive during the sample period (row 1, column 2), indicating that a unit of oil price rise will cause skipjack price to rise, and the impact gradually decreases with the increase of the lag period. The impact degree shows dynamic varying characteristics. Before 2010, the impact of oil price fluctuation on skipjack price remains high. In 2009, oil price rose by one unit, and Skipjack price rose 1.75 units (1.75%) after 3 months (see the red line). After 2010, the impact of oil price fluctuation on skipjack price decreased. After 2018, the impact degree of oil price remains at a low level. The impact of oil price on yellowfin price also changes positively during the sample period (row 1, column 3). Before 2010, the impact of oil price fluctuation on yellowfin price remains high, and reaches its peak in 2008. The oil price rose by one unit after 3 months, and the and the skipjack price rose by 1.25 units. After 2009, the impact of the oil price shock gradually decreased. Since 2018, oil price fluctuation has been in a high position. Since 2018, the dynamic impact effect has been at a lower level. The impact of oil prices on albacore prices shows a random trend during the sample period, indicating no significant correlation between them.

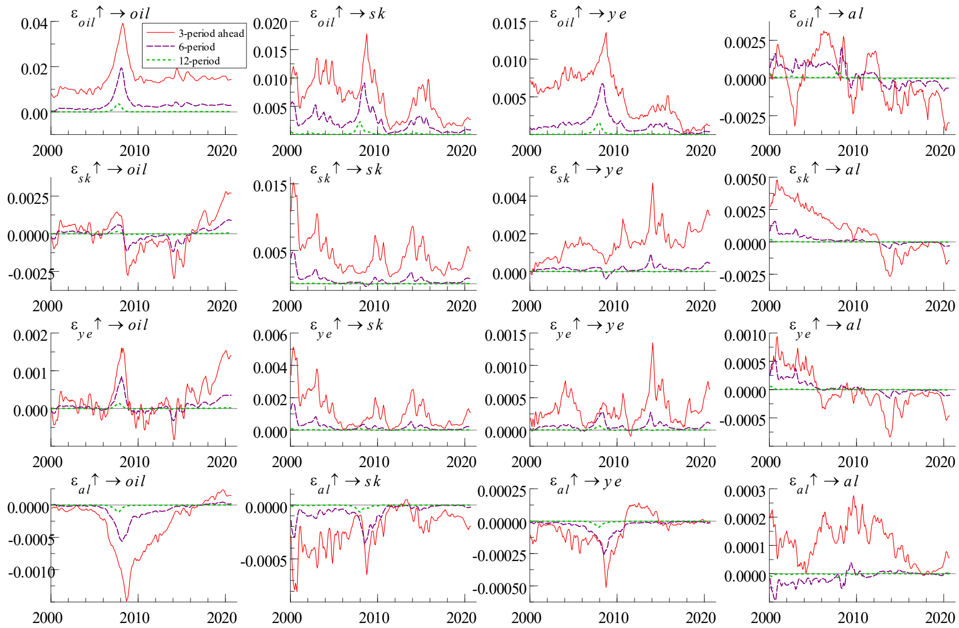

Figure 2. Time-varying impulse responses of the TVP-VAR model.

4.3. Time-varying characteristics based on time points

The above shows that the impact of oil price fluctuations on tuna price fluctuations changes over time. Next, the research focuses on the time points when crude oil prices fall, including December 2008 (due to the impact of the Financial Crisis), February 2016 (due to the impact of the US shale oil and gas revolution), and April 2020 (due to the impact of the global COVID-19). **Figure 3** shows the response of shocks at different time points. Subgraphs 2–4 of the first row, respectively, show the impact of falling oil prices on skipjack prices, yellowfin prices, and albacore prices.

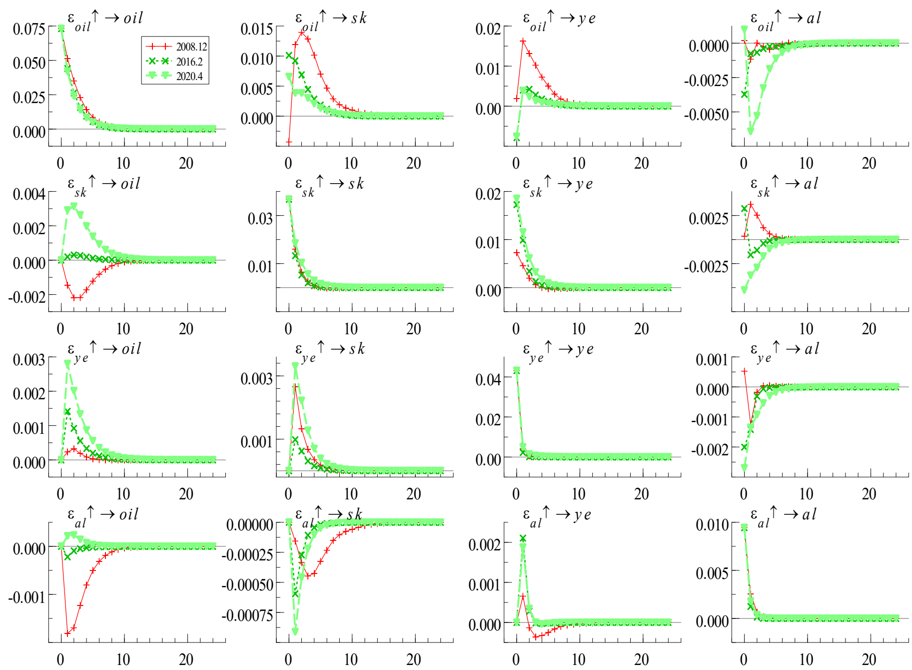

Figure 3. Time-varying impulse responses of the TVP-VAR model for time points.

It can be seen that the impacts of the oil price drop on skipjack price, yellowfin price, and albacore price are different at different time points (event impact). Affected by the Financial Crisis, the oil price dropped sharply in December 2008, causing a negative impact on the price of skipjack in the current period (phase 0), which turned to a positive impact after the first period. In the second period, the impact effect reached its maximum, then gradually declined, and then tended to zero after the 12th period (see the second subgraph in the first row, the red line). Oil price fluctuations have a positive impact on the yellowfin price in the current period, and the impact reached its maximum in the first period, then gradually attenuated and tended to zero after the 10th period (see the third subgraph in the first row, the red line). The impact of oil price fluctuations on the albacore price is negative, but the impact is small (see the fourth subgraph of the first row, red line). Influenced by the shale oil and gas revolution in the United States, oil prices dropped sharply in February 2016, with the largest positive impact on skipjack prices during the period and then gradually declining. At the time point of COVID-19 impact (April 2020), the impact of lower oil prices on the price of Skipjack shows a similar change (row 1, subgraph 2, green dotted and solid lines). At the time points of February 2016 and April 2020, the impact of the fall in crude oil prices on the yellowfin price is consistent; that is, the impact is negative in the current period, reaching its maximum positive impact after the first period, and then the impact effect gradually decreases (the third subgraph in the first row, the green dotted line, and the green solid line). In February 2016, the impact of the oil price decline on the Albacore price reached a negative maximum during the period and gradually approached 0 with the increase in time lag. In April 2020, the impact of the oil price decline on the albacore price was positive in the current period. After the first period, the negative impact of the oil price is the largest and then gradually tends to 0 (the fourth subgraph of the first row, the green dotted line, and the green solid line). In addition, other subgraphs in **Figure 3** show the impact of tuna price fluctuations on oil prices and their own. Finally, the impact effects all tend to 0, indicating that the TVP-VAR model is robust in describing the relationship between oil price and tuna price.

5. Discussion

This research contributes to the existing literature on investigating the price of crude oil on different commodities and presents an investigation of the time-varying effects of crude oil on the price of three tuna species, namely skipjack, albacore, and yellow fin. In this analysis, we show that the impact of crude oil price fluctuations on tuna price fluctuations is dynamic. During the period of 2000–2011, the impact coefficient of oil price fluctuation on skipjack price fluctuated around 0, and there was no significant correlation between oil price fluctuation and skipjack price fluctuation. After 2011, the impact coefficient of oil price fluctuation on Skipjack price shows a positive upward trend, and there is a positive correlation between them. For yellowfin, before 2009, the impact of oil price fluctuation on yellowfin price was positive; after 2009, oil price fluctuation had a negative impact on yellowfin price. During the sample period, the impact coefficient of the oil price on albacore varies around 0, and there is no significant correlation between the two. In addition, there is a dynamic correlation between the price fluctuations of different kinds of tuna. There is a significant positive correlation between the skipjack price and the yellowfin price, but there is no significant correlation with the albacore price.

In this study, specific phases related to the fluctuations of the oil price and its impact on the tuna price are also analyzed, focusing on the time points when crude oil prices fall, including December 2008 (due to the impact of the Financial Crisis), February 2016 (due to the impact of the US shale oil and gas revolution), and April 2020 (due to the impact of the global COVID-19). **Figure 3** shows the response of shocks at different time points. The analysis shows that the price of yellow fin and skipjack shows sensitivity to these phased oil price shocks but stays consistent after recovery.

6. Conclusions

This analysis shows that the relationship between oil prices and tuna prices depends on specific phases of oil price fluctuations and that global crude oil price shocks could have immediate and short-term impacts on fish markets, especially during a period of financial crisis. Since fuel is one of the most important cost drivers in fisheries, its impact on the price of tuna may be carefully investigated and taken into account for the long-term planning of fisheries management, in particular in areas where there is a heavy reliance on seafood as a source of food and income and limited national adaptive capacity, which may cause vulnerability to the fish. We recommend that tuna fishing organizations, along with the nations and regions where they operate, consider long-term planning scenarios for a range of oil price forecasts. These should include building resiliency into the plans for inevitable future price shocks with mitigation to allow the industry to overcome these short-term fluctuations.

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