Research Article

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Selected methods of securing the refining sector against crude oil price fluctuations

https://doi.org/10.2478/ijme-2018-0020
Received June 30, 2018; accepted September 5, 2018

Abstract: The contemporary refining sector has to contend with many types of risks, among which price risk is considered to be the foremost. Moreover, refineries define it as a commodity risk and identify it with both opportunities and threats carried by changes in prices of crude oil and products of refining. In this paper, we present selected methods that may protect enterprises in the refinery sector from the consequences of rapid fluctuations in oil prices. The focus is mostly on the opportunities offered by commodity options. Skillful combination of the above-mentioned derivatives in optional strategies enables hedging of the purchase prices of raw materials within fixed price ranges. In order to examine the effectiveness of using these strategies, the parameters of the commodity options from the New York Mercantile Exchange are utilized. The analysis of the West Texas Intermediate (WTI) crude oil prices covers the period from June 2014 to March 2018. Three different strategies from the vertical spread group have been taken into consideration, namely, short butterfly spread, long strip, and long strap. European call and put options with different strike prices have been used in the construction of these strategies. The comparison of the results achieved in the research indicates that there is an answer to the question of strategies that ought to be used at various levels of oil price changes. Moreover, the empirical results reveal that during rapid fluctuations in crude oil price (>10% month on month [MOM]), the median of most variants (80%) for the three considered strategies was positive. Furthermore, 70% of variants gave positive results, with price changes between 5% and 10%, whereas for price fluctuations of <5%, the strategies turned out to be an ineffective protection. The best results with rapid fluctuations in oil prices were obtained in the long strip strategy. Additionally, increasing the exercise price of options used in this strategy improved the mean for the final results. The higher exercise prices of the options also resulted in greater sensitivity of the effectiveness of the long strip strategy on the level of changes in oil prices. For the strategy variant with the At The Money (ATM)+10% options, the Pearson's correlation coefficient between the final result and the WTI oil prices in the analyzed period amounted to −0.91. For variants with the ATM+5% and ATM options, the value of this coefficient was −0.85 and −0.71, respectively. It is also worth noting that the consequence of increasing strike price in the long strip strategy was higher standard deviations for the final results. The empirical results might be useful information for oil refineries. It can help refineries to create a more successful price risk management policy, which may thus protect the companies from the negative consequences of unfavorable crude oil price movements.

Keywords: price risk, commodity options, option strategies
JEL: G32, Q02

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1 Introduction

A typical oil refinery purchases crude oil and sells refined products, such as liquid fuels and many others, which have a use in almost every branch of industry. In most countries (especially in Europe), their own crude oil resources are not sufficient to meet demand; hence, guaranteeing the liquidity of crude oil supplies is of crucial importance. It also seems that the most precarious moments on the market for a refinery are when rapid fluctuations in crude oil prices take place. This results in inability to predict the purchase costs. Furthermore, a refinery's financial condition is very sensitive to the level of refining margin – the spread between the prices of refined products and the price of crude oil. It is worth noting that since late 2005, a large decline in the refining margin has appeared to be quite common [Sukcharoen and Leatham, 2017, p. 493] and, in consequence, a large number of refineries have collapsed (especially in Europe).

The above-mentioned results of crude oil price volatility are defined by oil refineries as price risk. This is one of the main types of market risk (including the risk of variation in the interest rates and exchange rate risk) that these enterprises have to deal with on a daily basis. However, the empirical literature on oil price fluctuation results has started with studies examining the relationship between oil prices and the macroeconomy [Atil et al., 2014, p. 567]. Hamilton [1983] proves that there were statistically significant relationships between oil price fluctuations and real gross national product (GNP) growth for the U.S. economy in two periods: 1948–1972 and 1973–1980. He also shows that rising oil prices were responsible for seven of the eight U.S. recessions, in that time. Further empirical studies find a negative impact of oil prices on the growth of the economy not only for the USA [Hamilton, 1996, 2003] but also for European [Cunado and Perez de Gracia, 2003] and Asian countries [Cunado and Perez de Gracia, 2005; Kilian, 2009; Roache, 2012; Cross and Nguyen, 2017]. There is also evidence to support the existence of asymmetric and nonlinear links between oil price and economic growth, even though they have become weaker in the past few years [Hamilton, 2003, 2008; Kilian, 2008a, 2008b, 2008c, 2009; Lardic and Mignon, 2008].

In recent years, the impact of crude oil price fluctuations on other commodities and prices of refined products has been one of the most absorbing subjects of scientific research. One of the most interesting relationships that connect crude oil with prices of refined products was discovered by Bacon [1991] and named "rockets and feathers" effects. Bacon's empirical analysis showed that crude oil prices (production costs) tend to respond more rapidly to increases in gasoline prices than to decreases. In turn, Ji and Fan [2012] focused their studies on the causes and consequences of crude oil price volatility, including the influence of crude oil fluctuations on the values of nonenergy commodities before and after the financial crisis of 2007–2009. Most of the studies on the relationship between oil and natural gas focus on the investigation of the linear relations between these two prices [Asche et al., 2006; Villar and Joutz, 2006; Brown and Yucel, 2008; Hartley et al., 2008]. However, a slightly different approach in this matter was offered by Atil et al. [2014], who developed nonlinear autoregressive distributed lags (NARDLs) to study the impact of crude oil prices on the prices of gasoline and natural gas.

Apart from the influence of crude oil price on the macroeconomy and other commodity prices, expertise about underlying factors that may cause crude oil price volatility is crucial for oil refineries. It allows the companies to predict (more or less effectively) what may happen with the prices in the nearest future. Chai et al. [2011], in their proposed model, divided crude oil fluctuation factors into endogenous (demand, supply, and inventory level) and exogenous (net import value in China, US dollar [USD] index). The results of research revealed that after a period of rapid changes in oil prices (an intense increase was mostly between 2004 and 2008), the impact of some of these factors has also changed. The conclusion that suggests itself is that crude oil prices are currently characterized by greater sensitivity to the supply level. Moreover, the dwell time of this factor has become much shorter in comparison to the situation before the sharp fall in prices on the market in mid-2008. It is also worth noting that the above-mentioned uncertainty of crude oil price on the market volatility increased even more after a significant reduction in crude oil prices in the second half of 2014. As Czyżowski [2015] claims, the market lost its reference point in the moment when the strategy of the Organization of the Petroleum Exporting Countries (OPEC) was to look to the marginal costs of production to support oil prices, progressing from the physical market to the paper market.

It is also worth noting that due to unfavorable crude oil price movements, the risk of losses has intensified attempts to look for some new methods to avoid that risk. Use of commodity options is one of them. In the literature, we can mainly find analyses of the financial options that might be used for arbitrage, trading, and hedging. Císař and Dufala [2010] emphasized that the above-mentioned tools can be valuable for both individual and institutional investors. Amaitiek and Šoltés [2010] and Rešovský et al. [2010] conducted a deep search in the field of hedging usage of vanilla stock options. Yet, there is still a strong need to carry out further research in this field, as there are a few papers in literature regarding the use of commodity options in the risk management process. Accordingly, the goal of this paper is to show in theory and in practice, how three different option strategies, namely, short butterfly spread, long strip, and long strap, can be created, as well as how they can be used in the situation of extremely crude oil price fluctuations to hedge the cost production in refineries.

The remainder of this paper is organized as follows. In the first section, "Crude Oil Options", we present a short description of the commodity options and their role in the process of controlling the price risk in refineries. The next section, "Characteristics of Options Strategies", focuses on the construct of three vertical spread strategies, namely, short butterfly spread, long strip, and long strap. In this paper, we also attempt to examine the effectiveness of individual policy options. Following that, the historical scenario method is used. The WTI crude oil prices are selected as the research object, and the sample period ranges from June 23, 2014, to March 15, 2018. This can be found in the section "Data and Research Methodology". The final results are presented in the section entitled "Results and Conclusions".

2 Crude Oil Options

Commodity options are used by some countries to protect themselves before the negative consequences of crude oil price fluctuation hit them. These are mostly countries whose amount of the annual budget significantly depends on the crude oil price. One of these countries is Mexico – an important global oil exporter. Each year, the Mexican Finance Ministry plans to secure around one-fourth of total oil production using the purchase of commodity options. This standard practice has been used since the 1990s, and it was often successful for Mexico [Potocki, 2014, p. 224]. For instance, in 2014, the Mexican government paid $773 million (total option premium) for the right to sell crude oil at $76.4 per barrel. Considering that the average price of one barrel of Mexican crude oil Maya was <$50 in 2015, it is possible to assume that the option payment amounted to several billion US dollars (USDs) directed into the State budget. The Mexico government's policy, the major aim of which was to acquire sell options, continued in the following years. In 2015, the strike prices were set at $49 per barrel, paying an option premium of $1.09 billion [Martin, 2015]. In the next year, sales options were purchased with a performance price of $38 per barrel, incurring costs of $1.03 billion [Zhdannikov, 2017].

Commodity options are tools allowing the neutralization of the consequences of crude oil price fluctuation, which may affect a large number of countries and refining sector companies. It seems that the safest variant for both of them is to create collateral based on the options that are traded on the largest commodity exchanges in the world. Members of the exchange may count on such benefits as lower transaction costs or the integration of various oil markets that differ in their qualities and are located hundreds of miles away [Potocki, 2014, p. 224]. The most important institutions that focus on the trade of crude oil and refinery products are the New York Mercantile Exchange (NYMEX) and the InterContinental Exchange (ICE). Crude oil is also traded in other slightly smaller exchanges, which are situated in Rotterdam, Singapore, Oklahoma, or Boston. In the following paragraphs, a short description of the commodity exchange options listed on the NYMEX and ICE is presented.

The characteristics of the options are that they are contracts underlying which are the futures on crude oil prices (e.g., Light Sweet Crude Oil Futures) traded on the exchange. For these options, trading expires 3 business days before the termination of trading in the underlying futures contract. For example, for the WTI futures contracts, the time execution is set on the 25th of each month preceding the delivery month [CME Group, 2018]. In turn, the ICE Brent Crude Option Contract is based on the underlying ICE Brent Crude

Futures Contract, and the last trading day for this option is the day before the start of the month preceding the delivery month [ICE, 2018].

The options of crude oil prices are the most popular ones with regard to the above-mentioned exchanges. In the case of NYMEX, the highest turnover can be observed for the contracts related to the WTI oil crude price. As for ICE, Brent became the first and most popular crude oil futures contract. Additionally, options are also available for refining products such as diesel and gasoline. Commodity exchanges also provide their clients with options for the price difference of particular oil types (e.g., Brent – WTI) or the difference between the price of oil and finished products (e.g., Heating Oil – WTI).

The above presented options can be used to create more advanced methods that may protect oil refineries from the negative consequences of fluctuations in prices of crude oil and refinery products. It is worth noting that the combinations of several positions in options are defined as option strategies. Because there are a large number of option strategies, it is not possible to distinguish and present all of them; hence, only three vertical spread strategies, namely, short butterfly spread, long strip, and long strap, were chosen to be discussed in the paper. Their structures are based on taking positions of options that differ in their strike price or the type of option (call or put). The appropriate submission of options means that a given strategy can generate profits in various market conditions.

3 The Characteristics of Option Strategies

3.1 Short butterfly spread

First, we analyze the short butterfly spread. It can be constructed by taking four positions in three options of the same type, yet, with different strike prices. The butterfly spread uses either call or put options. Assuming that the strike prices of *K* meet a condition: *K1<K0<K2,* it is possible to distinguish the following types of short butterfly spread:

- Short call butterfly spread: taking one short position in the call option with the strike price *K1*, two long positions in the call option with a strike price *K0*, and one short position in the call option with a strike price *K2*.
- Short put butterfly spread: taking one short position in the put option with the strike price *K1*, two long positions in the call option with the strike price *K0*, and one short position in the put option with the strike price *K2*.

Assuming that *c(K)* is a premium for the European call option with the strike price *K*, whereas *fT* is the underlying price (e.g., crude oil futures price) at expiration date, the final results achieved in the short call butterfly spread strategy (*WBSC*) can be calculated using the following formula:

$$W_{BSC} = -\max\{f_T - K_1; 0\} + c(K_1) + 2\left[\max\{f_T - K_0; 0\} + c(K_0)\right] - \max\{f_T - K_2; 0\} + c(K_2). \quad (1)$$

On the other hand, according to the assumption that notes that *p(K)* is a premium for the European put option with strike price *K,* the final result achieved in the short butterfly spread strategy (*WBSP*) should be calculated using the following formula:

$$W_{BSP} = -\max\{K_1 - f_T; 0\} + p(K_1) + 2\left[\max\{K_0 - f_T; 0\} + p(K_0)\right] - \max\{K_2 - f_T; 0\} + p(K_2). \quad (2)$$

The results of the short butterfly spread strategy may take various forms, taking into account the range in which the *fT* price of the underlying instrument is implemented on exercise date (Table 1).

Table 1. The results achieved in short butterfly spread, depending on the price level of the underlying instrument on the expiry date of the option

Interval	Short call butterfly spread	Short put butterfly spread
$[0;K_1)$	$-c(K_1)+2c(K_0)-c(K_2)$	$K_2-2K_0+K_1-p(K_1)+2p(K_0)-p(K_2)$
$[K_1;K_0)$	$K_1-f_T-c(K_1)+2c(K_0)-c(K_2)$	$K_2+f_T-2K_0-p(K_1)+2p(K_0)-p(K_2)$
$[K_0;K_2)$	$2K_0-f_T-K_1-c(K_1)+2c(K_0)-c(K_2)$	$K_2-f_T-p(K_1)+2p(K_0)-p(K_2)$
$[K_2;\infty)$	$-K_2+2K_0-K_1-c(K_1)+2c(K_0)-c(K_2)$	$-p(K_1)+2p(K_0)-p(K_2)$

Source: own elaboration.

Moreover, the application of put–call parity (applies only to European Options) allows to show that, for the final result, it does not matter whether the call or put options are used in the construction of the short butterfly spread strategy [Hull, 2012, p. 351; Łamasz, 2017, pp. 146–147]. This means that the following relationship:

$$W_{BSC}=W_{BSP} \tag{3}$$

Therefore, in the next sections of the paper, it was decided not to indicate the type of option (call or put) that was used for the short butterfly spread. In both cases, the final results from the strategy were the same.

Since the short butterfly spread uses options with different strike prices, it is possible to modify the result profile achieved in these strategies by choosing different strike prices in the option. Figure 1 shows the potential results that could be achieved in the options listed for the WTI barrel on May 23, 2016, and expiring on June 16, 2016. The day when the hedge was formulated, the price of oil was $48 per barrel and it was the strike price of the At The Money (ATM) option.[1] The strike prices of the other options were 5% (ATM-5%, ATM+5%) and 10% (ATM-10%, ATM+10%) lower (–) or higher (+) than the strike price of the ATM option.

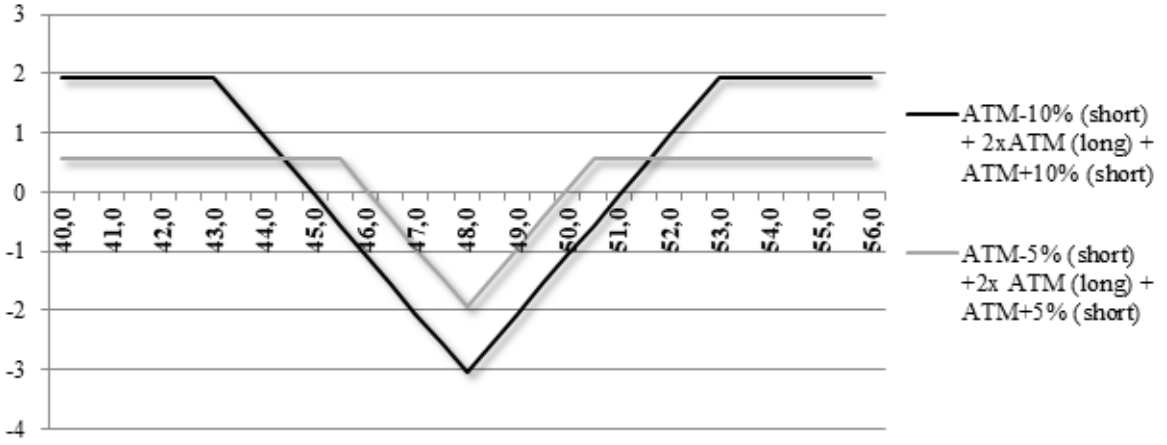

Figure 1. Short butterfly spread strategy example. Source: own elaboration.

1 The ATM option is an option in which the strike price is equal to the price of the underlying instrument on the day the contract is concluded.

Short butterfly spread gives a chance for a profit when the future price of the underlying instrument significantly differs from the strike price of the purchased options (Figure 1). Additionally, the greatest benefits can be achieved by using the solution in the construction of the strategy, according to which the difference in the strike prices of the "extreme" options is as large as possible. Hence, a short butterfly spread with ATM-10%, ATM, and ATM+10% options should bring better results in crude oil price fluctuations than ATM-5%, ATM, and ATM+5% ones. However, it should be noted that greater potential benefits are also associated with higher costs that might be incurred when the strategy fails. Such a situation occurs when there is a small change in the underlying price before the expiration of the strategy. It is also important to note that one can take short positions in options for which strike price is not symmetric to the strike price of the purchased options. For instance, in a strategy consisting of a short position in the options ATM-10% and ATM+5% and two long positions in the ATM option, it is possible to make a profit when significant deviations from the initial price of crude oil occur. Nonetheless, the best result will be achieved with pronounced declines, not price increases.

3.2 Long strip and long strap

We shall now focus on the strip and strap strategies. The main analysis is based on long positions in options (long strategies), as they are the only ones that enable to reduce the maximum losses regarding the hedger's choice of maximum level. Concurrently, it may give a chance for a profit in the situation of significant deviations of the underlying instrument prices from their initial ones. The construction of both strategies is quite similar and proceeds as follows:

- Long strip – purchase of one call option and two put options with the same strike prices;
- Long strap – purchase of two call options and one put option with the same strike prices.

On the basis of the above, there are three long options that are used in this type of protection against crude oil price fluctuation. The final results achieved in the long strip ($W_{\text{Long Strip}}$) and long strap ($W_{\text{Long Strap}}$) can be calculated using the following formulas:

$$W_{\text{Long Strip}} = \max\{f_T - K; 0\} - c(K) + 2 \cdot \left(\max\{K - f_T; 0\} - p(K)\right), \tag{4}$$

$$W_{\text{Long Strap}} = 2 \cdot \left(\max\{f_T - K; 0\} - c(K)\right) + \max\{K - f_T; 0\} - p(K). \tag{5}$$

Taking long positions for call and put options with the same strike prices may protect the market against declines and increases of the underlying instruments. Long strip is a strategy primarily focused on declines. This means that potentially greater benefits can be achieved when the value of the commodity on the day the strategy is exercised is below the strike price of the option. On the other hand, two long positions in the call option result in the long strap becoming a growth-oriented strategy. Hence, hedgers may choose this type of protection, as they may expect much higher underlying prices in the future. Exemplary long strip and long strap strategy profiles are illustrated using Figures 2 and 3.

By selecting ATM options in the long strip strategy, the hedger ought to be aware of significant changes from the value of the underlying instruments that might appear in the future (Figure 2). The price decrease will be much more favorable due to the purchase of two put options. On the other hand, by selecting ATM options in the long strap strategy, the hedger should expect an increase that may allow to make much greater profit than the price decrease of the underlying instrument (Figure 3).

Similarly to the short butterfly spread strategy, the final results achieved with the use of long strip and long strap can be changed by replacing the ATM option with an option with a higher or lower strike price. The more the option price is shifted to the left, the better result will be achieved regarding the future price increase of the underlying instrument. By shifting the strike price to the right, one can guarantee a profit in a situation when the value of the underlying instrument decreases. Nonetheless, it should be noted that such modifications may entail an increase in the initial costs (which equals the sum of the option's premium). Additionally, if the market conditions (future prices of underlying instrument) do not change

according to the hedger's forecasts, the final result might become a significant financial burden for him/her. Hence, such "shifts" ought to be used carefully.

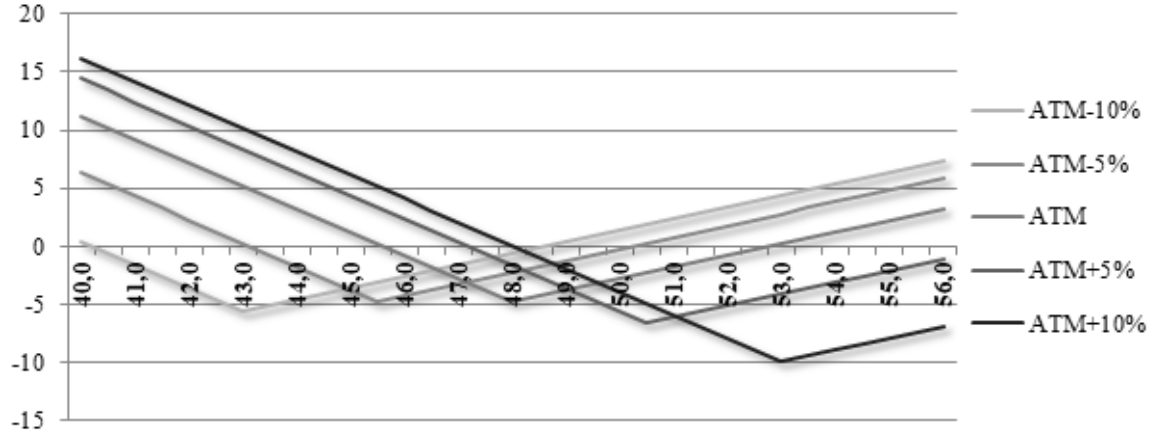

Figure 2. Example of long strip strategy. Source: own elaboration.

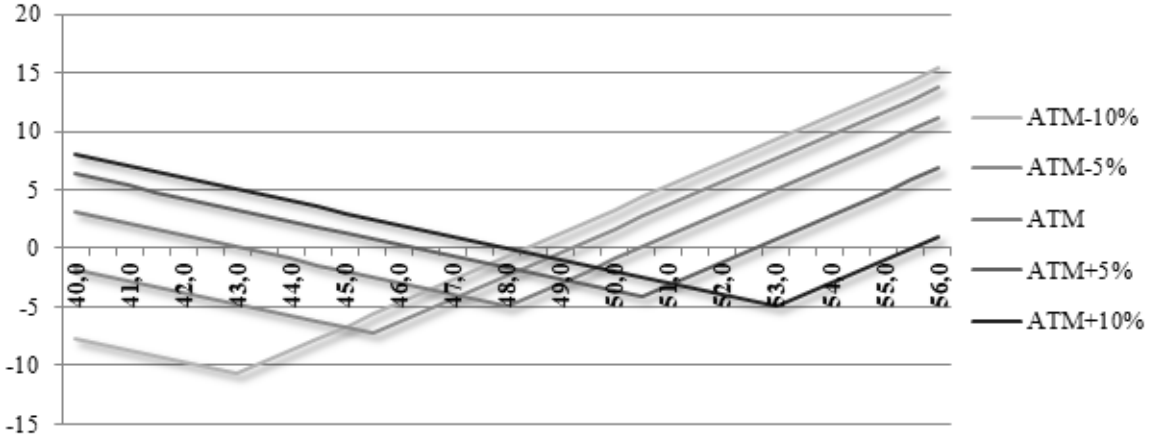

Figure 3. Example of long strap strategy. Source: own elaboration.

4 Research Data and Methodology

The short butterfly spread, long strip, and long strap strategies were examined for their effectiveness at various levels of crude oil price changes. The analysis concerned the WTI crude oil future prices, and the sampling period ranged from June 23, 2014, to March 15, 2018.

On this basis, we attempted to establish the results achieved in the above-mentioned strategies. Additionally, the results referred to specific crude oil delivery months, ranging from August 2014 to April 2018 (45 consecutive months). For instance, in order to construct the strategy for crude oil delivery in August 2014, we used the long or short position in European (call or put) options written on June 23, 2014,[2] expiring on July 17, 2014. It was the period for which the results of the buying and selling (call and put) options with different strike prices were established. Subsequently, the results of strategies were obtained from the process of taking positions in the above-mentioned options. Such a procedure was applied for each

2 The first day in which the crude oil future option price for August delivery was the nearest to the futures price.

of the 45 months. The amount of option premiums with different strike prices (ATM-10%, ATM-5%, and so on) was established in accordance with Black's model, which takes into consideration the valuation of the commodity options [Black, 1976, pp. 167–171].

The following types of option contracts were used in order to create the option strategies:

- ATM-10% options – options with a strike price 10% lower than the ATM option strike price;
- ATM-5% options – options with a strike price 5% lower than the ATM option strike price;
- ATM options;
- ATM options + 5% – options with a strike price 5% higher than the ATM option strike price;
- ATM options + 10% – options with a strike price 10% higher than the ATM option strike price.

As a result, 20 variants of the previously discussed strategies were obtained, including the following:

- short butterfly spread strategies (10),
- long strip strategies (5),
- long strap strategies (5).

Their effectiveness was tested depending on the level of crude oil price changes over the period considered. For this purpose, each of the 45 months was assigned to one of three categories:

- Category 1: monthly[3] change in crude oil price was at least 10%;
- Category 2: monthly change in crude oil price ranged from 5% to 10%;
- Category 3: monthly change in crude oil price was <5%;

Months and the level of changes are presented in Table 2. Each category comprises 15 months. The largest changes (Category 1) were dominated by months (nine of them) in which there was a decrease of WTI price. In the other two categories, the ratio of decrease to increase was 8:7 (Category 2) and 7:8 (Category 3).

Table 2. Percentage changes (MOM) of WTI crude oil prices in the construction of strategy during the period of activity of the options

Change (month on month)					
Above 10%		**5%–10%**		**Less than 5%**	
Increase	**Decrease**	**Increase**	**Decrease**	**Increase**	**Decrease**
02.2015 (11.52%)	12.2014 (–26.89%)	05.2015 (6.59%)	08.2014 (–5.49%)	09.2014 (0.45%)	07.2014 (–2.65%)
04.2015 (19.39%)	01.2015 (–12.65%)	08.2016 (5.15%)	10.2014 (–9.62%)	10.2015 (4.22%)	06.2015 (–0.96%)
09.2015 (15.80%)	03.2015 (–12.20%)	10.2016 (9.76%)	11.2014 (–6.04%)	02.2016 (3.93%)	04.2016 (–2.75%)
03.2016 (20.19%)	07.2015 (–16.54%)	12.2016 (7.16%)	11.2015 (–9.62%)	02.2017 (0.21%)	06.2016 (–3.73%)
05.2016 (12.35%)	08.2015 (–14.55%)	04.2017 (9.69%)	07.2016 (–6.22%)	08.2017 (2.37%)	01.2017 (–0.04%)
01.2018 (10.29%)	12.2015 (–14.41%)	07.2017 (8.28%)	09.2016 (–9.52%)	09.2017 (2.87%)	05.2017 (–0.87%)
	01.2016 (–13.33%)	11.2017 (7.12%)	03.2017 (–8.88%)	10.2017 (2.73%)	03.2018 (–0.41%)
	11.2016 (–10.18%)		02.2018 (–5.18%)	12.2017 (1.86%)	
	06.2017 (–13.67%)				

Source: own elaboration.

3 The term "monthly" means the period of activity of the discussed options, which is usually from 23 to 28 days.

5 Results

The main objective of the study was to compare the collateral offered by option strategies with regard to significant fluctuations in crude oil prices. Hence, the final analysis focuses on the results obtained from the months from Category 1. Table 3 presents the median values obtained from the results for each month with the use of option strategies. The results of the other two categories are presented in Tables A1 and A2. The final results show how many monetary units (USD) could be gained or lost regarding the particular option strategy per barrel of WTI. The tables also include parameters of options used to apply the particular strategy variant, as well as information regarding the choice of position (long or short).

Table 3. The median values (USDs per barrel) achieved in crude oil price fluctuations exceeding 10% (Category 1)

Strategies	Variant		USD/barrel
	Long position	Short position	
Long strip	ATM+10% (C) + 2× ATM+10% (P)		8.52
Long strip	ATM+5% (C) + 2× ATM+5% (P)		7.09
Long strip	ATM (C)+ 2× ATM (P)		4.35
Long strap	2× ATM+10% (C) + ATM+10% (P)		3.29
Long strip	ATM-5% (C)+ 2× ATM-5% (P)		3.24
Short butterfly spread	2× ATM+5%	ATM-10% + ATM+10%	2.87
Long strap	2× ATM (C) + ATM (P)		2.56
Long strap	2× ATM+5% (C)+ ATM+5% (P)		2.33
Short butterfly spread	2× ATM	ATM-10% + ATM+5%	1.73
Short butterfly spread	2× ATM	ATM-10% + ATM+10%	1.65
Short butterfly spread	2× ATM+5%	ATM-5% + ATM+10%	1.52
Long strip	ATM-10% (C) + 2× ATM-10% (P)		1.07
Short butterfly spread	2× ATM	ATM-5% + ATM+5%	0.45
Short butterfly spread	2× ATM+5%	ATM + ATM+10%	0.40
Short butterfly spread	2× ATM-5%	ATM-10% + ATM	0.29
Short butterfly spread	2× ATM	ATM-5% + ATM+10%	0.13
Short butterfly spread	2× ATM-5%	ATM-10% + ATM+5%	−0.38
Short butterfly spread	2× ATM-5%	ATM-10% + ATM+10%	−0.93
Long strap	2× ATM-5% (C) + ATM-5% (P)		−1.33
Long strap	2× ATM-10% (C) + ATM-10% (P)		−6.39

Source: own elaboration.

The results presented in Table 3 confirm that most of the strategies selected for the ongoing analysis allow to successfully protect against crude oil price fluctuation. The median appeared to be a positive number in 16 out of 20 variants. Long strip strategies provided the best results. Presumably, their dominance is caused by the advantage of downward trend (there were 9 months of decline and 6 months showing increase). At the very end of the list, there were, in turn, long strap strategies for which options with the performance price were set at a low level (ATM-5% or ATM-10%).

Taking into account the long strip strategy, ATM+10%, ATM+5%, and ATM occurred to be the best options. Nonetheless, it should be noted that increasing the strike prices in these strategies results in an increase in the cost of collateral. These strategies consist of two long positions in the sales options, the price of which increases when the strike price is increased. Table 4 describes this issue more carefully (Variant 1 – ATM+10% call and put options; Variant 2 – ATM+5% call and put options; Variant 3 – ATM call and put options), including the results achieved in each of the 15 analyzed months, as well as selected statistical data.

Table 4. The results (USDs per barrel) and statistics for the best long strip strategy in Category 1

Month	Changes (MoM, %)	Options		
		ATM+10%	ATM+5%	ATM
12.2014	−26.89%	40.58	38.93	35.08
01.2015	−12.65%	10.86	8.77	5.02
02.2015	11.52%	−15.09	−8.63	−3.19
03.2015	−12.20%	8.52	5.93	2.62
04.2015	19.39%	−8.64	−2.41	2.74
07.2015	−16.54%	18.88	17.00	13.75
08.2015	−14.55%	14.12	11.99	8.36
09.2015	15.80%	−5.79	−1.23	2.16
12.2015	−14.41%	10.96	9.30	6.74
01.2016	−13.33%	8.23	7.27	5.11
03.2016	20.19%	−7.86	−5.10	−2.71
05.2016	12.35%	−9.10	−3.81	−0.64
11.2016	−10.18%	8.61	7.09	4.35
06.2017	−13.67%	13.08	11.84	9.50
01.2018	10.29%	−12.02	−4.15	2.10
	Median	8.52	7.09	4.35
	Mean	5.02	6.19	6.07
	Standard deviation	14.82	11.82	9.20
	Number of losses	6	6	3
	Number of profits	9	9	12
	Pearson correlation coefficient for changes and results	−0.91	−0.85	−0.71

Source: own elaboration.

The analysis of Table 4 shows that the process of increasing the option strike price in long strip strategies resulted in increased sensitivity of results to fluctuations in crude oil prices. Among the 15 analyzed months in Category 1, there were 9 months in which decrease in crude oil prices was noticed. Similarly, there were 9 months in which we could notice the profit in variants with options ATM+10% or ATM+5%. A strong, inverse correlation between the level of price changes and the results was found with the use of Pearson correlation coefficient (for ATM+10%: −0.91; for ATM+5%: −0.85). This indicator was significantly lower in the variant with ATM options (−0.71). Additionally, the above-mentioned strategy variant enabled to make a profit from 12 of the 15 months in Category 1. It is also worth comparing the average results in the three analyzed variants of the long strip strategy in the months with decreasing or increasing WTI prices. In the "decreasing months", the mean for ATM+10% was 14.87USDs per barrel; for ATM+5%, it was 13.12USDs per barrel; and for ATM, it was 10.06USDs per barrel. On the contrary, in the "increasing months", the variant with the ATM option was much more efficient (with mean equaling 0.08USDs per barrel) compared with the variants ATM+10% or ATM+5% (the mean for them was respectively equal to −9.75 and −4.22USDs per barrel).

The results suggest that the use of ATM options in the long strip strategy appears to be a more comprehensive protection from rapid changes of crude oil prices. Contrarily, variants with options with other strike prices are more preferable when hedgers are firmly convinced of the future direction of price changes.

Furthermore, long strip strategies yielded the best results regarding lower crude oil price changes (5%–10% MOM; Table A1). It is worth emphasizing that in such market conditions, most of the analyzed strategy variants provided positive results. Yet, the situation was different in the months when the crude oil price fluctuation did not exceed 5%. Only 2 out of 20 offered chances for profits (Table A2). The above-mentioned statements allow us to claim that such strategies as short butterfly spread, long strip, and long strap ought to be utilized only during significant fluctuations in the underlying instrument prices.

6 Conclusions

The refining sector is one of the most vulnerable to any changes in global markets. The main reason is the fact that crude oil, which is processed in petroleum refineries on a daily basis, has been the most important energy resource for many years. Moreover, the demand for it continues to grow. Nevertheless, its main deposits are still within the territory of countries with sociopolitical conflicts. Thus, it is assumed that both geopolitical factors and the decisions of the OPEC cartel and Russia will be of crucial importance for shaping crude oil prices in the upcoming years.

The high volatility of crude oil prices requires the continued and necessary search for solutions that would allow refineries' financial condition to be independent of price fluctuations. One of such solutions is the use of option strategies presented in this paper. Both, the short butterfly spread strategy and the long strip or long strap enable establishment of the maximum loss when they are constructed. This means that they cannot be treated as speculative strategies. Undoubtedly, their advantage is that they do not require precise predictions of crude oil price changes (especially for variants with ATM options). Moreover, their construction uses options with different strike prices. In accordance with that, the hedger is able to set collateral in the price range he/she specifies.

It is worth noting that the presented solutions can be used by refineries to secure both purchase costs and revenues from the sale of raw materials. Due to the necessity of maintaining crude oil reserves at a fixed level, the above-mentioned enterprises are exposed to risk related to changes in crude oil inventories. The results achieved in the option strategies can therefore provide some compensation to neutralize the negative consequences of real price changes in the market.

This study was conducted under a research project funded by a statutory grant of the AGH University of Science and Technology in Krakow for maintaining research potential.

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Appendix

Table A1. Median values (USDs per barrel) achieved in crude oil price changes ranging from 5% to 10% (Category 2)

Strategy	Variant		USD/barrel
	Long position	Short position	
Long strip	ATM+10% (C) + 2× ATM+10% (P)		6.25
Long strip	ATM+5% (C) + 2× ATM+5% (P)		5.10
Long strap	2× ATM+10% (C) + ATM+10% (P)		2.85
Short butterfly spread	2× ATM+5%	ATM-10% + ATM+10%	2.46
Short butterfly spread	2× ATM+5%	ATM-5% + ATM+10%	1.76
Long strip	2× ATM (P) + ATM (C)		1.68
Long strap	2× ATM (C) + ATM (P)		1.50
Short butterfly spread	2× ATM	ATM-10% + ATM+10%	1.31
Long strap	2× ATM+5% (C) + ATM+5% (P)		1.21
Short butterfly spread	2× ATM	ATM-5% + ATM+10%	1.18
Short butterfly spread	2× ATM	ATM-10% + ATM+5%	0.56
Short butterfly spread	2× ATM	ATM-5% + ATM+5%	0.53
Short butterfly spread	2× ATM-5%	ATM-10% + ATM	0.45
Short butterfly spread	2× ATM +5%	ATM + ATM+10%	0.38
Short butterfly spread	2× ATM-5%	ATM-10% + ATM+5%	−0.39
Short butterfly spread	2× ATM-5%	ATM-10% + ATM+10%	−0.59
Long strip	ATM-5% (C) + 2× ATM-5% (P)		−0.90
Long strip	ATM-10% (C) + 2× ATM-10% (P)		−3.43
Long strap	2× ATM-5% (C) + ATM-5% (P)		−3.48
Long strap	2× ATM-10% (C) + ATM-10% (P)		−6.62

Source: own elaboration.

Table A2. Median values (USDs per barrel) achieved in crude oil price changes below 5% (Category 3)

Strategies	Variant		USD/barrel
	Long position	Short position	
Short butterfly spread	2× ATM-5%	ATM-10% + ATM	0.37
Short butterfly spread	2× ATM+5%	ATM + ATM+10%	0.12
Short butterfly spread	2× ATM-5%	ATM-10% + ATM+5%	−0.02
Short butterfly spread	2× ATM-5%	ATM-10% + ATM+10%	−0.46
Long strip	ATM-10% (C) + 2× ATM-10% (P)		−0.66
Short butterfly spread	2× ATM	ATM-5% + ATM+5%	−0.80
Short butterfly spread	2× ATM+5%	ATM-5% + ATM+10%	−0.81
Long strap	2× ATM-10% (C) + ATM-10% (P)		−0.99
Short butterfly spread	2× ATM	ATM-5% + ATM+10%	−1.13
Short butterfly spread	2× ATM	ATM-10% + ATM+5%	−1.17
Long strap	2× ATM+10% (C) + ATM+10% (P)		−1.23
Long strip	ATM-5% (C) + 2× ATM-5% (P)		−1.25
Short butterfly spread	2× ATM+5%	ATM-10% + ATM+10%	−1.26
Short butterfly spread	2× ATM	ATM-10% + ATM+10%	−1.63
Long strap	2× ATM-5% (C) + ATM-5% (P)		−1.67
Long strip	ATM+10% (C) + 2× ATM+10% (P)		−1.75
Long strap	2× ATM+5% (C) + ATM+5% (P)		−2.34
Long strip	ATM+5% (C) + 2× ATM+5% (P)		−2.59
Long strap	2× ATM (C) + ATM (P)		−3.48
Long strip	ATM (C) + 2× ATM (P)		−3.72

Source: own elaboration.