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The Effect of Hedging Price Risk with Crude Oil Derivatives

Abstract

This study aims to analyze hedging through option strategies against adverse price fluctuations. The methodology involves developing an analytical framework to establish a price ceiling for evaluating the effect of price risk management. This approach facilitates comparisons among different hedging option strategies across various potential price scenarios. The research focuses specifically on theoretical derivations applied within the crude oil market to explore how specific parameters influence the selection of optimal hedging strategies. Additionally, it compares these strategies with those proposed in prior research. The findings suggest recommendations for employing option strategies that align with anticipated future price movements. By incorporating real-world applications in hedging crude oil portfolios, this study aims to enhance its practical relevance. This research fills the gap in the current body of knowledge on hedging using option strategies. Limitations may arise in terms of generalizing results from a single variable, i.e., profitability.

Keywords: energy market, hedging, option strategies, price fluctuation

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1. INTRODUCTION

In the era of globalization, characterized by rapid information exchange, price risk has become increasingly significant. Economic events are swiftly mirrored in the price fluctuations of financial assets. Price risks are frequently referred to as potential losses in the financial markets caused by fluctuations in the price of stocks, currencies, interest rates, and commodities (Janabi, 2009). Energy market prices, such as crude oil prices, are currently more volatile than those of other commodities. This fact makes it difficult to manage a business and create long-term plans for both producers and consumers since it increases the probability of uncertainty in forecasts for future prices. Most of the studies concerning oil price volatility have been conducted, for example Lu et al. (2020), Nonejad (2020), Chatziantoniou et al. (2021), Bourghelle, Jawadi & Rozin (2021), Guo et al. (2022), among others. These papers provides framework for crude oil analysis and forecasting and they serve as an initial point for hedging strategies. Price risk management is the process of mitigating potential risks that may affect the achievement of a firm's objectives. The most common tools for managing price risk are diversification and hedging using derivatives. Diversification means participating in a variety of markets to reduce exposure to the risk of any one particular market. Recent research in the crude oil market has primarily focused on the spillover effects and portfolio strategies between crude oil, natural gas, precious metals, and stock markets. Abid et al. (2020) analyze the dynamic conditional correlation between the US equity market and various commodity prices. They determine and compare optimal hedge ratios from different models based on their hedging effectiveness, finding that gold is the most effective hedging asset. Mensi, Al Rababa'a & Kang (2021) examine asymmetric return spillovers between crude oil futures, gold futures, and ten sector stock markets in China, concluding that investors benefit from adding gold and oil to their equity portfolios. Salisu, Vo, & Lawal (2021) study the role of gold as a hedge against crude oil price risks confirming the hedging effectiveness of gold and other precious metals, including silver, platinum, and palladium, against oil-related risks. Jebabli, Kouaissah, & Arouri (2022) investigate volatility spillovers between energy and stock markets during the COVID-19 pandemic. Researcher also emloyed different investment asset, such as Bitcoin to minimize losses associated with crude oil prices. Bitcoin is significantly correlated with global financial assets such as crude oil and gold (Liu et al., 2024).

On the other hand, the term hedging refers to risk management by applying derivatives. Forwards, futures, options, and swaps are all examples of derivative instruments. The derivative tool that serves as the subject of investigation in this study is an option. An option is a financial contract that grants its holder the right, but not the obligation, to buy or sell an underlying asset at a predetermined price within a specified period. As mentioned by Thanekar & Shaikh (2021), options are an important type of derivative that have the ability to specifically determine a portfolio's price risk. As the price of the underlying asset fluctuates, the option price changes accordingly, offering opportunities for hedging against price movement.

Łamasz & Iwaszczuk (2020) stated that oil price fluctuations are particularly significant for oil exporting countries, as they greatly influence the economic conditions of these countries. In contrast, in oil-importing economies, an increase in oil prices is generally linked to greater economic and financial uncertainty, which tends to reduce investments and delay major consumer purchases, such as cars, housing, and appliances (Charfeddine & Barkat, 2020). Crude oil prices also impact various economic aspects, including the stock market prices (Mokni, 2020, Jiang & Yoon, 2020), economic growth and the inflation rate (Wang et al., 2022), and the cost of alternative energy sources (Murshed & Tanha, 2021). Consequently, it is crucial to explore hedging methods that can mitigate the negative effects of crude oil price fluctuations on national economies and individual enterprises, particularly in the energy sector.

The aim of this paper is to analyze various options strategies that allow crude oil buyers to choose the right combination of options to mitigate risk from crude oil price increases. By using call and put options and their combinations, investors can maximize gains or minimize losses. The literature is reviewed with a focus on hedging using option strategies. In the context of existing literature, this

paper discussed the strip, long strangle, and short call ladder strategies. One of the objectives of the paper is to present the profit functions of hedged positions using the above-mentioned strategies. The theoretical analysis is applied to the crude oil option market. For the application of these strategies, it is essential to calculate the parameters of these strategies (break-even points and price ceilings). All the calculations made in the paper refer to to the WTI crude oil options (traded on the NYMEX). The practical application shows how to hedge to minimize the impact of potentially adverse price moves in the decision-making processes of price risk management. The next objective is to perform a profitability analysis of the designed hedging possibilities for crude oil future price scenarios. The article concludes with a comparison of the analyses performed in risk management and their implications for oil-dependent investors and companies. This study endeavors to contribute to a more comprehensive understanding of the broader context in which these strategies operate, shedding light on their potential applications for risk management in the crude oil market.

The rest of the paper is structured as follows: Section 2 presents the literature review. Section 3 outlines the methodology used. Section 4 discusses hedging crude oil prices using option strategies such as strip, long strangle, and short call ladder, along with their effects and comparisons to other option strategies against price increases. Section 5 provides a discussion by summarizing the findings and comparing them with existing research.

2. LITERATURE REVIEW

Options, as derivative instruments, can be utilized by market participants in various ways. Speculators trade options to profit from declines, increases, or stability in the prices of the underlying assets (such as stocks, bonds, currency exchange rates, gold, oil, and gas). Conversely, hedgers use options as tools to mitigate the risk of price fluctuations in underlying assets. The option hedging strategies serves different purposes and suits various market conditions and profit-risk profiles.

Many works focus on the concept of option hedging based on the Greeks from the option valuation models. The Black-Scholes model, developed by Black & Scholes (1973) and Merton (1973), is founded on the principle that the no-arbitrage value of an option equals the initial cost of its replication strategy. Extended versions of this model include stochastic volatility models such as those by Stein & Stein (1991), Heston (1993), Lee (2005), and Ball & Roma (2009). Carr & Wu (2014) compared static hedging with dynamic delta hedging. Studies on delta hedging for options were also presented by Crépey (2004), Vähämaa (2004), Alexander et al. (2012), Hull & White (2017), and Xia, Yang & Zhu (2023). Buehler et al. (2018) introduced a framework for hedging a portfolio of derivatives utilizing deep reinforcement learning techniques tailored for stochastic processes. They showed the effect on hedging under transaction costs in a synthetic market driven by the Heston model. Model for option replication and hedging based on deep reinforcement learning proposed the authors Du et al. (2020).

Another approach to hedging with options is through the use of some common types of hedging strategies. Each of these strategies can be tailored to specific risk management goals and market views. The choice of strategy depends on factors such as the investor's risk tolerance, market outlook, and the specific characteristics of the underlying asset. Studies on options hedging strategies have focused on the performance of the covered call strategy or the protective put strategy (Figlewski Chidambaran & Kaplan, 1993, Dewobroto et al., 2010, Mugwagwa et al., 2012, Israelov & Nielsen, 2015, Diaz & Kwon, 2016, Niblock & Sinnewe, 2018, Kedžo & Šego, 2021). Hedging with collar strategies has been presented in the paper by Bartonova (2012), Israelov & Klein (2017). Commodity risk management using collar and ratio spread strategy was investigated by Taušer & Čajka (2014). Authors discussed and compared different hedging techniques and pointed out their advantages and disadvantages. Various studies have explored the performance of options strategies such as straddle, strangle, and butterfly. Chen & Leung (2003), Fullwood, James, & Marsh (2021) specifically analyzed straddle strategies. Bangur (2020a), (2020b) analyse the performance of strangle and strip option strategies. Additionally, Basson, Berg, & Vuuren (2018) recommended butterfly strategies for achieving

Table 1: Summary of studies on hedging using option strategies

	Option strategies	Hedging against decrease/increase	Underlying asset
Figlewski, Chidambaran, & Kaplan (1993)	protective put	decrease	stock
Dewobroto et al. (2010)	covered call protective put collar	decrease	stock
Bartonova (2012)	collar	decrease	currency
Mugwagwa et al. (2012)	covered call	slighty decrease	stock
Tauser & Čajka (2014)	colar ratio spread	decrease	wheat
Israelov & Nielsen (2015)	covered call	slighty decrease	stock
Rusnáková (2015)	long put long combo inverse vertical ratio put spread	decrease	wheat
Diaz & Kwon (2016)	covered call	slighty decrease	index
Israelov & Klein (2017)	collar	decrease	index
Basson, Berg, & Vuuren (2018)	collar butterfly	decrease	index
Harčariková (2018)	strap long strangle short put ladder	decrease	corn
Niblock & Sinnewe (2018)	covered call	slighty decrease	index
Bangur (2020a)	strangle	both	index
Bangur (2020b)	strip	increase	index
Bobriková (2021)	long call short combo vertical ratio call back spread	increase	wheat
Fullwood, James, & Marsh (2021)	straddle	both	currency
Kedžo & Šego (2021)	covered call protective put collar	decrease	stock
Shivaprasad et al. (2022)	covered call covered put collar synthetic long call	decrease	stock

	Option strategies	Hedging against decrease/increase	Underlying asset
Alam (2022)	straddle strangle strap strip	both	–
Chen & Leung (2003)	straddle	both	currency
Yang (2023)	bull spread bear spread box spread butterfly spread calendar spread straddle	both	–
This study	strip long strangle short call ladder	increase	crude oil

Source: Authors' overview

controlled profit with limited risk. Harčariková & Šoltés (2016, 2017) explored hedging techniques in the energy sector using barrier options. These researchers achieved full protection against price drops or increases using classical vanilla options and more complex exotic options. They found that options used for managing market risk produce significant reductions in that risk.

While studies have explored various options strategies, comparative studies specifically focusing on these strategies are less common. There is a lack of research comparing options strategies. Evaluating and comparing options hedging strategies is essential for investors to trade and hedge their investments effectively. Rusnáková (2015) demonstrated the application of bearish option strategies such as the long put, long combo, and inverse vertical ratio put spread for risk management. Harčariková (2018) analyzed the strap, long strangle, and short put ladder hedging strategies with the aim of proving how it is possible to hedge against falling prices. These authors focused on commodity sellers who hedge against price declines and performed an analysis and comparison of hedging through option strategies.

Bobriková (2021) conducted a comparative analysis of the long call, short combo, and vertical ratio call back spread strategies. The hedging effectiveness of the covered call, covered put, collar, and synthetic long call strategies, along with a comparison of their payoffs, was discussed in the paper by Shivaprasad et al. (2022). Alam (2022) presented option strategies such as straddle, strangle, strap, and strip. Additionally, Yang (2023) proposed different option strategies that enable investors to choose the right combination to mitigate risk and achieve higher returns under different circumstances.

Table 1 shows the summary of studies on hedging strategies using vanilla options. This study builds upon previous research that focused on comparing various option hedging strategies. The objective is to examine the impact of hedging through specific option strategies, namely strip, long strangle, and short call ladder. Identifying and analyzing these selected option strategies addresses a gap in current research within this domain. This research aims to bridge this gap by conducting a profitability analysis of option hedging strategies.

The study presents several distinctions from prior research: (I) It addresses a gap in the literature by analyzing hedging strategies involving the strip, long strangle, and short call ladder options, which have not been comprehensively studied. (II) It

applies these hedging strategies to the crude oil market, a context not previously explored in existing research. This introduces a unique market dynamic that may differ significantly from other commodities. (III) It includes a comparative analysis of these hedging option strategies against existing research, providing new insights into their effectiveness.

3. METHODOLOGY

This research used the approach of profit function of option strategies and derived hedge positions for various scenarious of future price development. The approach also made it possible to investigate the parameters that determine the prices of hedge portfolios which can help in risk management decision-making. The effect of price risk hedging through option strategies becomes evident when comparing profit functions with and without hedging.

All options strategies are based on the four basic types of option: short or long positions in call or put options. A call (or put) option is a type of financial security that gives its holder the right to purchase (or sell) an underlying asset at a strike price in a future date. The writer of the call (or put) option has the obligation to sell (or buy) the asset. The position of option holder is long (position of buying) and the position of option writer is short (position of selling). The buyer of the option pays a premium to the seller of the option. The premium is the cost of an option for the rights conveyed by an option.

All participants in the options market concentrate on the price of the underlying asset at the contract's expiration day. This price is the key from the point of view of a success of option strategies created by options. Table 2 illustrates the profit or loss associated with long and short positions in call and put options with the strike price *X,* the unit amount *n*, the market price of the underlying asset S_T at the expiration date *T* and premium *p.*

Table 2: Profit/loss from basic option positions for possible future price scenarios

	Future price scenarios	Profit/ loss from option position
Long call	$S_T<X$	$-n*p$
	$S_T\geq X$	$n(S_T-X-p)$
Short call	$S_T<X$	$n*p$
	$S_T\geq X$	$-n(S_T-X-p)$
Long put	$S_T<X$	$-n(S_T-X+p)$
	$S_T\geq X$	$-n*p$
Short put	$S_T<X$	$n(S_T-X+p)$
	$S_T\geq X$	$n*p$

Source: Authors' overview

While numerous option strategies are employed for trading and speculative purposes, only a select few are specifically designed for hedging. Each hedging strategy offers unique advantages and limitations, with the choice of strategy depending on the investor's objectives, risk tolerance, and the characteristics of the assets being safeguarded. Furthermore, a thorough understanding of the mechanics and potential outcomes of these strategies is crucial for effective risk management.

Long hedging is the strategy used to protect against rising prices. In this context, the buyer anticipates needing to buy some asset in the future and is concerned about potential price increases. Spot market position is an unhedged position expressed as:

$$-n*S_T \quad (1)$$

A hedged position involves using options to reduce the risk of adverse price movements in an asset. By taking a hedged position, an investor offsets potential losses in a spot market position by making future market position that will gain if the initial one loses. The formula for calculating a hedged position is as follow:

$$\text{Hedged Position}=\text{Unhedged Position}+\text{Option Strategy Position} \quad (2)$$

Table 3: Option hedging strategies suitable for a price increase

	Market direction	Volatility	Profit profile	Risk profile
Strip	bearish neutral	high	unlimited	limited
Long strangle	neutral	high	unlimited	limited
Short call ladder	bullish	high	unlimited	limited

Source: Authors' overview

The selection of option strategies is based on a comprehensive review of the aforementioned literature. Table 3 presents the key characteristics of the selected option strategies.

Strip strategy involves simultaneously holding long positions in both call and put options on the same underlying asset with identical expiration dates. Additionally, the strike prices of these options are set at the same level. This strategy assumes twice as many positions in put options compared to call options. Therefore, to calculate the final outcome of the strip strategy, it is essential to detail the final results of the long positions in both put and call options using the correct parameters, and subsequently structure them appropriately for the strategy.

Assuming that X is the strike price of an option, n is the unit amount of an option, S_T is the market price of the underlying asset at the expiration date T, p_1 is premium for a call option, p_2 is premium for a put option, the profit function $P(S_T)$ of strip strategy is:

$$P(S_T) = \begin{Bmatrix} -n\left(2S_T - 2X + p_1 + 2p_2\right) & if\ S_T < X \\ n\left(S_T - X - p_1 - 2p_2\right) & if\ S_T \geq X \end{Bmatrix} \quad (3)$$

This strategy is well-suited for traders who expect substantial fluctuations in the underlying price. These fluctuations may occur in either direction, but there is a higher likelihood of a decrease in price. Due to its reliance on long options, it is expensive. While this strategy appears straightforward, it is recommended that only experienced hedgers employ it.

The long strangle strategy is categorized as a market-neutral options strategy wherein an investor simultaneously purchases both call and put options with identical expiration dates. Strike prices for these options can vary widely. The initial cost of buying both options (call and put) can be significant, so the price movement needs to be large enough to cover this cost and generate a profit. In summary, this strategy is designed for traders expecting a big price move in the underlying asset, irrespective of whether the movement is upwards or downwards. The profit function associated with the long strangle strategy is as follows:

$$P(S_T) = \begin{Bmatrix} -n(S_T - X_2 + p_1 + p_2) & if\ S_T < X_1 \\ n\left(X_2 - X_1 - p_1 - p_2\right) & if X_1 \leq\ S_T \geq X_2 \\ n(S_T - X_1 - p_1 - p_2) & if\ S_T \geq X_2 \end{Bmatrix} \quad (4)$$

The short call ladder strategy involves selling a call option at a strike price X_1 with a premium p_1, purchasing an equivalent quantity of a higher strike price call option at a strike price X_2 with a premium p_2, and subsequently purchasing another equivalent quantity at an even higher strike price X_3 with a premium p_3. The profit function of the strategy is expressed as follows:

$$P(S_T) = \begin{Bmatrix} n\left(p_1 - p_2 - p_3\right) & if\ S_T < X_1 \\ -n(S_T - X_1 - p_1 + p_2 + p_3) & if X_1 \leq\ S_T \geq X_2 \\ n\left(X_1 - X_2 + p_1 - p_2 - p_3\right) & if X_2 \leq\ S_T \geq X_3 \\ n(S_T + X_1 - X_2 - X_3 + p_1 - p_2 - p_3) & if\ S_T \geq X_3 \end{Bmatrix} \quad (5)$$

Table 4: The comprehensive theoretical analysis of hedging using option strategies for potencial future scenarios

	Future price scenarios	Unhedged position	Profit/loss from the strategy	Hedged position
Strip	$S_T<X$	$-n*S_T$	$-n(2S_T-2X+p_1+2p_2)$	$-n(3S_T-2X+p_1+2p_2)$
	$S_T\geq X$	$-n*S_T$	$n(S_T-X-p_1-2p_2)$	$-n(X+p_1+2p_2)$
Long strangle	$S_T<X_1$	$-n*S_T$	$-n(S_T-X_2+p_1+p_2)$	$-n(2S_T-X_2+p_1+p_2)$
	$X_1\leq S_T<X_2$	$-n*S_T$	$n(X_2-X_1-p_1-p_2)$	$-n(S_T-X_2+X_1+p_1+p_2)$
	$S_T\geq X_2$	$-n*S_T$	$n(S_T-X_1-p_1-p_2)$	$-n(X_1+p_1+p_2)$
Short call ladder	$S_T<X_1$	$-n*S_T$	$n(p_1-p_2-p_3)$	$-n(S_T-p_1+p_2+p_3)$
	$X_1\leq S_T<X_2$	$-n*S_T$	$-n(S_T-X_1-p_1+p_2+p_3)$	$-n(2S_T-X_1-p_1+p_2+p_3)$
	$X_2\leq S_T<X_3$	$-n*S_T$	$n(X_1-X_2+p_1-p_2-p_3)$	$-n(S_T-X_1+X_2-p_1+p_2+p_3)$
	$S_T\geq X_3$	$-n*S_T$	$n(S_T+X_1-X_2-X_3+p_1-p_2-p_3)$	$n(X_1-X_2-X_3+p_1-p_2-p_3)$

Source: Authors' summary

If the condition $p_1 > p_2 + p_3$ is met, the zerocost condition is fulfilled, and it is a so-called no-initial cost option strategy. This strategy is employed when there is an expectation of significant upward movement in the underlying asset's price.

The comprehensive theoretical analysis of hedging using option strategies is detailed in Table 4, offering a structured framework for the practical application and comparison of unhedged and hedged prices. Hedged prices are formulated according to the formula (2).

From the point of view of successfully implementing each option strategy, the price ceiling and break-even point (BEP) are the important parameters. A price ceiling denotes the maximum limit on the price of the underlying asset, beyond which the price cannot rise. Establishing an effective price ceiling is essential for managing risk and ensuring that the hedging strategy is robust and effective. The calculation formulas for the price ceiling are derived from the hedged positions and are detailed as follows:

Strip strategy:

$$-(X + p_1 + 2p_2) \quad (6)$$

In this strategy, the price ceiling is set by combining the strike price X with the premiums p_1 and $2p_2$. This formula ensures that the maximum purchase price is capped, thereby providing a clear threshold above which the asset's price will not rise, protecting the buyer from adverse price movements.

Long strangle:

$$-(X_1 + p_1 + p_2) \quad (7)$$

Short call ladder:

$$-(X_1 - X_2 - X_3 + p_1 - p_2 - p_3) \quad (8)$$

Establishing precise price ceilings through these formulas empowers hedgers to mitigate risk exposure strategically. By aligning these strategies with market conditions, they can optimize their hedging positions to achieve specific risk management objectives.

The Break-Even Point (BEP) is the price at which the hedged price using one strategy equals the hedged price using another strategy or the unhedged price. Hence, the BEP signifies the price level of the underlying asset where the final outcomes of the compared strategies are equivalent. BEPs are calculated using analytical profit functions of hedged or unhedged positions (see Table 4).

4. CRUDE OIL OPTION HEDGING STRATEGIES AGAINST A PRICE INCREASE

Crude oil option hedging against price increases is advantageous for buyers – consumers, refineries, and other entities dependent on crude oil, aiming to mitigate exposure to elevated prices. A primary strategy involves purchasing call options with a strike price slightly above the current market rate. Should crude oil prices exceed the strike price, the hedger may exercise these options to procure crude oil at the predetermined lower rate, thereby limiting the maximum price paid. Effective crude oil option hedging necessitates adeptness in selecting suitable strategies aligned with specific risk management goals, which requires an understanding of options trading and market dynamics to effectively implement and manage the hedging strategy.

4.1. Data

Data was taken from NYMEX, which also offers metals, agricultural contracts, and products related to energy. Light sweet crude oil european options with an expiration date of May 2025 are included in the dataset. The details of the option contract are presented in Table 5, whereas Table 6 shows the call and put option premiums in $ per barrel at the actual date, which is January 17, 2024. A single option contract in crude oil represents 1,000 barrels.

Table 5: Contract details for crude oil options

Underlying asset	Light sweet crude oil futures May 2025
Contract unit	1,000 barrels
Minimum Price Fluctuation	0.01 per barrel = $10
Settlement date	17/01/2024
Actual price at 17/01/2023	81.01 per barrel
Future date	May 2025

Source: CME Group

Table 6: Premiums for call and put options on crude oil ($/per barrel)

Call option premium	Strike price	Put option premium
11.96	77.5	10.58
11.74	78	10.86
11.52	78.5	11.14
11.30	79	11.42
11.09	79.5	11.71
10.88	80	12.00
10.68	80.5	12.30
10.48	81	12.60
10.28	81.5	12.90
10.09	82	13.21

Source: CME Group

4.2. Hedging results using strip, long strangle and short call ladder strategies

In practical application, the concept involves a potential hedger – specifically, a crude oil buyer anticipating a demand of 1,000 barrels in October – who adopts options strategies to safeguard

Table 7: Hedging using strip strategy I (in USD/per barrel)

Future price scenarios	Unhedged price	Profit/loss from the strategy	Hedged price
S_T<80	-S_T	-2S_T+125.12	-3S_T+125.12
S_T≥80	-S_T	S_T-114.88	-114.88

Source: Authors' calculations

Table 8: Comparative analysis of strip hedging variants (in $/barrel)

Future crude oil price scenarios	Hedged price using strip I at the strike 80		Hedged price using strip II at the strike 77.5	
	Profit function	Profit intervals	Profit function	Profit intervals
S_T<77.5	-3S_T+125.12	**(-107.38; 125.12)**	-3S_T+121.88	(-110.62; 121.88)
77.5≤S_T<78.58	-3S_T+125.12	**<-107.38; -110.62)**	-110.62	<-110.62; -110.62)
78.58≤S_T<80	-3S_T+125.12	<-110.62; -114.88)	-110.62	**<-110.62; -110.62)**
80≤S_T	-114.88	<-114.88; -114.88)	-110.62	**<-110.62; -110.62)**

Source: Authors' calculations

against potential price escalations. By utilizing these hedging strategies, the hedger aims to minimize exposure to volatile market conditions and ensure the price of crude oil during the specified period.

Strategy 1 – Strip: The buyer can now purchase 1 October crude oil call option contract at $10.88 per barrel and 2 October crude oil put option contracts at $12 per barrel, both with a strike price of $80. Table 7 presents the unhedged position, option strategy position, and hedged position, each expressed in terms of price per barrel. The strip strategy incorporates hedging by establishing a price ceiling at $114.88 per barrel, as outlined in formula (6).

Assume the construction of a strip option strategy with a strike price of $77.5 per barrel. Table 8 compares the strip hedging variants at different strike prices. Strip I, with a strike price of $80, offers better hedging results if the price is below $78.58. Above this BEP, strip II, with a strike price of $77.5, is more effective. BEP is the price at which the hedged price using strip I equals the hedged price using strip II (-3S_T+125.12=-110,62). The analysis highlights the sensitivity to strike prices: a lower strike price results in a lower price ceiling. However, if the price drops only slightly, the strip with the higher strike price performs better in hedging.

Strategy 2 – Long strangle: Three design possibilities are being considered for this strategy:

- Buying 1 October crude oil call option contracts at a strike price of $77.5 with a premium of $11.96 per barrel, and buying 1 October crude oil put option contracts at a strike price of $80 with a premium of $12 per barrel (LS I).

Table 9: Hedging using long strangle strategy (in $/per barrel)

	Future price scenarios	Unhedged price	Profit/loss from the strategy	Hedged price
LS I	S_T<77.5	-S_T	-S_T+56.04	-2S_T+56.04
	77.5≤S_T<80	-S_T	-21.46	-S_T-21.46
	80≤S_T	-S_T	S_T-101.46	-101.46
LS II	S_T<77.5	-S_T	-S_T+56.83	-2S_T+56.83
	77.5≤S_T<82	-S_T	-20.67	-S_T-20.67
	82≤S_T	-S_T	S_T-102.67	-102.67
LS III	S_T<80	-S_T	-S_T+57.91	-2S_T+57.91
	80≤S_T<82	-S_T	-22.09	-S_T-22.09
	82≤S_T	-S_T	S_T-104.09	-104.09

Source: Authors' calculations

Table 10: Comparative analysis of long strangle strategy hedging variants I and II (in $/per barrel)

Future crude oil price scenarios	Hedged price using LS I	Hedged price using LS II
	Profit intervals	
S_T<77.5	(-98.96; 56.04)	**(-98.17; 56.83)**
77.5≤S_T<80	<-98.96; -101.46)	**<-98.17; -100.67)**
80≤S_T<80.79	<-101.46; -101.46)	**<-100.67; -101.46)**
80.79≤S_T<82	**<-101.46; -101.46)**	<-101.46; -102.67)
82≤ S_T	**<-101.46; -101.46)**	<-102.67; -102.67)

Source: Authors' calculations

- Buying 1 October crude oil call option contracts at a strike price of $77.5 with a premium of $11.96 per barrel, and buying 1 October crude oil put option contracts at a strike price of $82 with a premium of $13.21 per barrel (LS II).
- Buying 1 October crude oil call option contracts at a strike price of $80 with a premium of $10.88 per barrel, and buying 1 October crude oil put option contracts at a strike price of $82 with a premium of $13.21 per barrel (LS III).

Table 9 details the hedged prices and their corresponding price ceilings: $101.46 for LS I, $102.67 for LS II, and $104.09 for LS III (as specified in formula (7). The Long strangle strategy anticipates substantial movement in the underlying asset in either direction. This approach considers three potential future commodity price scenarios. If the price of the asset stays within the range of the strike prices, it results in the maximum potential loss.

Table 11: Comparative analysis of long strangle strategy hedging variants II and III (in $/per barrel)

Future crude oil price scenarios	Hedged price using LS II	Hedged price using LS III
	Profit intervals	
S_T<77.5	(-98.17; 56.83)	**(-97.09; 57.91)**
77.5≤S_T<78.58	<-98.17; -99.25)	**<-97.09; -99.25)**
78.58≤S_T<80	**<-99.25; -100.67)**	<-99.25; -102.09)
80≤S_T<82	**<-100.67; -102.67)**	<-102.09; -104.09)
82≤ S_T	**<-102.67; -102.67)**	<-104.09; -104.09)

Source: Authors' calculations

Table 12: Hedging using short call ladder strategy (in $/per barrel)

Future price scenarios	Unhedged price	Profit/loss from the strategy	Hedged price
S_T<77.5	-S_T	-9.01	-S_T-9.01
77.5≤S_T<80	-S_T	-S_T+68.49	-2S_T+68.49
80≤S_T<82	-S_T	-11.51	-S_T-11.51
82≤S_T	-S_T	S_T-93.51	-93.51

Source: Authors' calculations

The comparative analysis of hedging variants LS I and LS II is depicted in Table 10. LS I proves more effective as a hedging variant when the underlying asset price exceeds the BEP of $80.79; otherwise, LS II is preferable. A lower strike price of the put option correlates with a lower price ceiling.

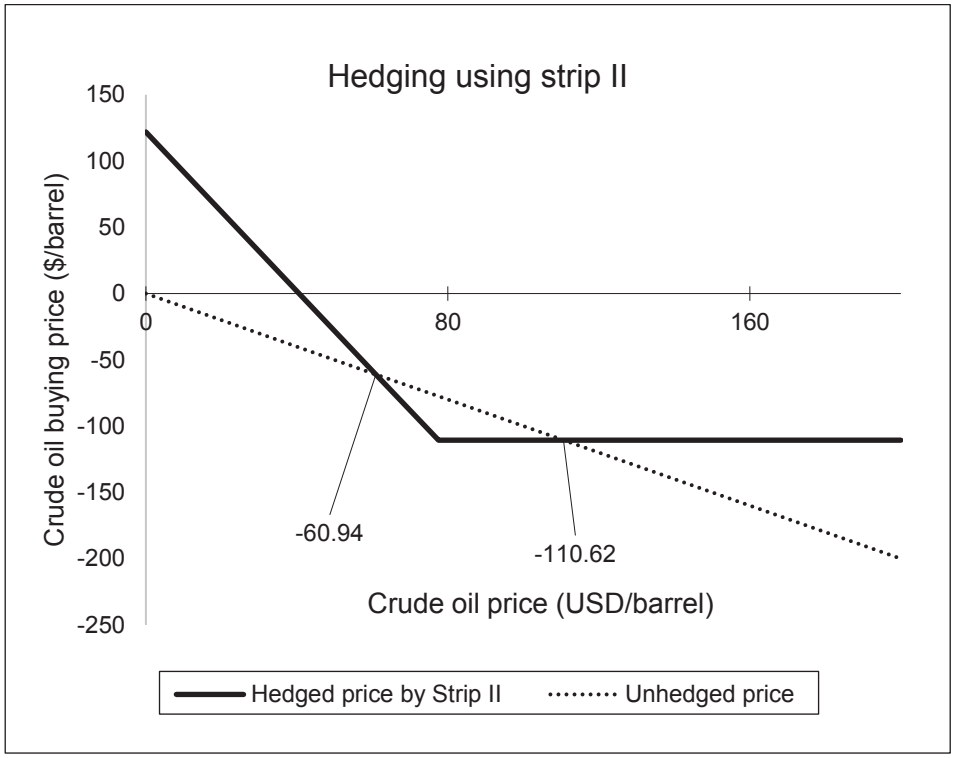
The comparative analysis of hedging variants LS II and LS III examines the sensitivity of prices based on different call strike points. The results are presented in Table 11. If the price of the underlying asset exceeds the BEP of $78.58, LS II proves to be the superior hedging variant. A lower strike price of the call option corresponds to a higher price ceiling.

Strategy 3 – Short call ladder: Suppose the buyer of crude oil implements a short call ladder strategy, involving selling an October crude oil futures call option contract at a strike price of $77.5 with an option premium of $11.96 per barrel. Additionally, they purchase a call option contract at a strike price of $80 with an option premium of $10.88 per barrel, and another call option contract at a strike price of $82 with an option premium of $10.09 per barrel. Table 12 illustrates the hedged prices for future scenarious. The ceiling for the purchasing price is established at $93.51 per barrel, as indicated in formula (8).

4.3. Effect of hedging using strip, long strangle and short call ladder strategies

The effect of hedging, whether positive or negative, is assessed by comparing the hedged price to the unhedged price. If the hedged buying price is lower than the unhedged buying price, hedging is considered to have a positive effect. Conversely, if the hedged buying price is higher, hedging has a negative effect.

Graph 1: Unhedged prices and hedged crude oil prices using strip strategy II



Graph 1 illustrates the functions for hedged and unhedged crude oil prices. If the underlying price rises above $110.62, the hedged position will generate a better price in comparison to the unhedged position (an unlimited positive effect of hedging). The crude oil buyer achieves possitive effect of hedging if the price moves significantly in either direction, also if the price of underlying falls downward. The negative effect of hedging arises when the price of the underlying asset remains close to the strike price (a maximum negative effect is $34.88).

Table 13 illustrates the effect of hedging through option strategies, specifically strip II, long strangle I, and short call ladder. Based on the observed positive and negative effects of these hedging strategies, the following conclusions can be drawn:

- The short call ladder strategy ensures the lowest purchase price for crude oil if the future price exceeds $65.445. The positive effect of hedging (i.e., securing a better price than an unhedged position) becomes particularly advantageous if the crude oil price surpasses $93.51, reflecting a 15.43% price increase. The negative effect of hedging is observed within the $0-$93.51 range.
- The strip II strategy guarantees the lowest crude oil purchase price for future prices between $0 and $60.94, with a positive hedging effect. However, for price increases above this range, this strategy underperforms compared to other hedging strategies by yielding the highest purchase price.
- For crude oil price fluctuations between $60.94 and $93.51, an unhedged position offers the best purchase price, outperforming the option strategies.
- The long strangle I strategy establishes a mid-range price ceiling for crude oil. Compared to an unhedged position, the positive

Table 13: Effect of hedging using strip II, long strangle I and short call ladder (in $/per barrel)

Future crude oil price scenarios	Positive or negative effect of hedging					
	Strip II		Long strangle I		Short call ladder	
	Min	Max	Min	Max	Min	Max
S_T<56.04	**9.8**	**121.88**	0	56.04	-9.01	-9.01
56.04≤S_T<60.94	**0**	**9.8**	-4.9	0	-9.01	-9.01
60.94≤S_T<65.05	**-8.22**	**0**	-9.01	-4.9	-9.01	-9.01
65.05≤S_T<65.445	**-9.01**	**-8.22**	-9.405	-9.01	-9.01	-9.01
65.445≤S_T<65.84	-9.8	-9.1	-9.8	-9.405	**-9.01**	**-9.01**
65.84≤S_T<77.5	-33.12	-9.8	-21.46	-9.08	**-9.01**	**-9.01**
77.5≤S_T<80	-33.12	-30.62	-21.46	-21.46	**-11.51**	**-9.01**
80≤S_T<82	-30.62	-28.62	-21.46	-19.46	**-11.51**	**-11.51**
82≤S_T<93.51	-28.62	-17.11	-19.46	-7.95	**-11.51**	**0**
93.51≤S_T<101.46	-17.11	-9.16	-7.95	0	**0**	**7.95**
101.46≤S_T<110.62	-9.16	0	0	9.16	**7.95**	**17.11**
110.62≤S_T<200	0	89.38	9.16	98.54	**17.11**	**106.49**
200≤S_T	89.38	∞	98.54	∞	**106.49**	**∞**

Source: Authors' calculations

hedging effect increases significantly with price movements in either direction.

- In situations characterized by pronounced price volatility in either direction, it is recommended to utilize the long strangle strategy.

4.4. Comparison with previously examined option hedging strategies

The previous section concludes on the relevance of the short call ladder in mitigating financial exposure arising from increasing market valuations. Moreover, the comparion with other option hedging strategies suitable against a price increase is desirable. Effect of hedging using option strategies, namely long call, short combo and vertical ratio call back spread implicated on this paper dataset is stated in Table 14.

The short combo strategy yields a positive hedging effect if the future price exceeds $80.3 per barrel and incurs the lowest negative effect when the price ranges from $77.5 to $80.3. However, in the event of a significant price decrease, it has the greatest negative hedging effect. Therefore, this strategy is optimal for hedging against potential price increases. Its risk-reward profile is meticulously balanced, allowing hedgers to manage exposure to price growth effectively. For unpredictable price movements in either direction, the short call ladder, long call or vertical ratio call back spread strategies are advisable. This adaptability is crucial for hedgers seeking to mitigate risks and safeguard their positions in a dynamic market environment.

Table 14: Effect of hedging using short call ladder, long call, short combo and vertical ratio call back spread (in $/per barrel)

Future crude oil price scenarios	Positive or negative effect of hedging							
	Short call ladder		Long call		Short combo		Vertical ratio call back spread	
	Min	Max	Min	Max	Min	Max	Min	Max
S_T<65.84	**-9.01**	**-9.01**	-11.96	-11.96	-11.96	-77.8	-9.8	-9.8
65.84≤S_T<68	**-9.01**	**-9.01**	-11.96	-11.96	-9.8	-11.96	-9.8	-9.8
68≤S_T<68.79	**-9.01**	**-9.01**	-11.96	-11.96	-9.01	-9.08	-9.8	-9.8
68.79≤S_T<77.5	-9.01	-9.01	-11.96	-11.96	**-0.3**	**-9.01**	-9.8	-9.8
77.5≤S_T<78.58	-9.01	-10.09	-10.88	-11.96	**-0.3**	**-0.3**	-9.8	-10.88
78.58≤S_T<78.975	-10.09	-10.485	-10.485	-10.88	**-0.3**	**-0.3**	-10.88	-11.275
78.975≤S_T<80	-10.485	-11.51	-9.46	-10.485	**-0.3**	**-0.3**	-11.275	-12.3
80≤S_T<80.3	-11.51	-11.51	-9.16	-9.46	**-0.3**	**0**	-12	-12.3
80.3≤S_T<80.79	-11.51	-11.51	-8.67	-9.16	**0**	**0.49**	-11.51	-12
80.79≤S_T<82	-11.51	-11.51	-7.46	-8.67	**0.49**	**1.7**	-10.3	-11.51
82≤S_T<89.46	-4.05	-11.51	-7.46	0	**1.7**	**9.16**	-2.84	-10.3
89.46≤S_T<92.3	-1.21	-4.05	0	2.84	**9.16**	**12**	-2.84	0
92.3≤S_T<93.51	-1.21	0	2.84	4.05	**12**	**13.21**	0	1.21
93.51≤S_T<200	0	106.49	4.05	110.54	**13.21**	**119.7**	1.21	107.7
200≤S_T	106.49	∞	110.54	∞	**119.7**	**∞**	107.7	∞

Source: Authors' calculations

5. DISCUSSION

This section discusses the effect of using option strategies to hedge against price increases. Evaluating the effectiveness of these strategies requires an understanding of the profit/loss profiles associated with each one, including considerations of various parameters such as the price ceilings and the break-even points.

The results showed that, the short combo strategy stands out for its ability to be implemented with a positive hedge effect during price stagnation. This strategy can generate the desired protection with an attractive hedge profit. A significant advantage is its cost-free establishment. This strategy sets a minimum price ceiling but restricts potential gains from price decreases due to the short put position setting a price floor. The spread between the ceiling and floor prices depends on the choice of strike prices; a larger difference between strike prices results in a wider spread between the ceiling and floor prices. These findings align with those previously reported by Bobriková (2021).

Further, the results indicate that the short call ladder strategy is more adept at mitigating price risk in declining markets compared to the vertical ratio call back spread strategy. When prices drop, it shows the least negative hedging effect.

Table 15: Essential facts about option hedging strategies against a price increase

	Direction	Positive hedge effect	The best hedge profit profile	No-initial cost
Strip	bearish neutral	significant decrease or increase	significant decrease	no
Long strangle/Long straddle	neutral	significant decrease or increase	–	no
Short call ladder	bullish	significant increase	significant decrease or increase	yes
Long call	bullish	moderate increase	–	no
Short combo	bullish	increase	minimal fluctuation or increase	yes
Vertical ratio call back spread	bullish	significant increase	–	yes

Source: Authors' overview

The vertical ratio call back spread strategy, which involves a combination of short and long options to achieve a zero-cost setup, contrasts with this effectiveness. Moreover, the study compares the vertical ratio call back spread and strip strategies. Both strategies derive their price spread not just from the selection of strike prices, but also from the quantity of options involved.

The analysis of the strip strategy revealed that a lower strike price positively influences the price ceiling. However, when the price drops only slightly, the strip strategy with a higher strike price demonstrates better hedging performance. The profit formulas for strip option strategies provide valuable insights for academicians to calculate and understand profitability analysis (Bungur, 2020b).

Hedgers utilize the long straddle and long strangle strategies, when expecting significant price movements without a clear directional bias. As noted by Yang (2023), the straddle strategy can be costly since it involves purchasing two options instead of one. Investors must also consider the break-even points of this strategy, which depend on the premiums paid for the options and the chosen strike prices. Chen and Leung (2003) and Fullwood, James, and Marsh (2021) have examined long-short straddle positions. This study identified three design possibilities for the long strangle strategy. Comparative analysis of hedging variants confirmed a positive correlation between a lower strike price and a lower price ceiling, consistent with the findings of Bungur (2020a) and Alam (2022).

The basic bullish strategy, long call, sets a maximum purchase price for an option premium while enabling participation in price decreases. The results of the long call strategy indicate a midpoint in its buying price, supporting the findings of Bobriková (2021).

Table 15 serves as a comprehensive summary of option hedging strategies, providing essencial information that can guide hedgers in making informed decisions going forward. Such tables typically condense key details, such as the types of strategies, their direction, the effects of hedging, possibly scenarios where each strategy is most effective, and the cost of implementing the hedge This summary can be invaluable for hedgers looking to manage risk effectively in their financial activities.

6. CONCLUSION

The fundamental challenge in every market lies in the inherent unpredictability of future prices. Option strategies are widely recognized for their effectiveness in hedging against this uncertainty. Despite this, only a small fraction of market participants actively utilize options in their operations. For those with a solid understanding of options, they represent a versatile and powerful tool for managing price risk, offering a range of approaches to risk management.

This study explores three specific option strategies, strip, long strangle, and short call ladder, applied within the theoretical framework of hedging crude oil prices against potential increases. The findings illustrate that all hedging strategies establish a price ceiling. The short call ladder strategy ensures the lowest purchase price for crude oil in case of a price increase. Conversely, the strip strategy, while more expensive initially, compensates with twice the protection in the event of price decreases. The long strangle strategy, cheaper than strip, offers a lower purchase price in case of price increases but a higher one in case of decreases. All results underscore the significant impact of strike prices on hedging outcomes.

Furthermore, comparisons with other option hedging strategies long call, short combo, and vertical ratio call back spread, reveal that the short combo strategy yields the highest hedging profits. This strategy's ability to capitalize on upward price movements positions it as an optimal choice for mitigating risks associated with rising prices. However, it is important to note its limitations, particularly in scenarios of significant price declines.

This comprehensive research and analysis provide valuable insights for hedgers, facilitating decision-making. By combining theoretical foundations with empirical evidence, the study enriches the understanding of the advantages and disadvantages associated with employing option strategies for hedging against potential price increases. This research addresses gaps in current knowledge on hedging practices using options, contributing original findings through comparative analyses of various hedging strategies. Moreover, it emphasizes the importance of aligning these strategies with specific goals and risk tolerances of hedgers seeking protection from adverse price movements.

References

Abid, I., Dhaoui, A., Goutte, S., & Guesmi, K. (2020). Hedging and diversification across commodity assets. *Applied Economics*, *52*(23), 2472-2492. DOI: 10.1080/00036846.2019.1693016.

Alam, S. I. (2022). The 4S of Option Trading Strategies: Straddle, Strangle, Strap, Strip. *Journal of Economic Studies and Financial Research*, 16-22.

Alexander, C., Rubinov, A., Kalepky, M., & Leontsinis, S. (2012). Regime-dependent smile-adjusted delta hedging. *Journal of Futures Markets*, *32*(3), 203-229. Available at SSRN: https://ssrn.com/abstract=1678460.

Al Janabi, M. A. M. (2009). Commodity price risk management: Valuation of large trading portfolios under adverse and illiquid market settings. *Journal of Derivatives and Hedge Funds, 15*(1), 15-50. DOI:10.1057/jdhf.2008.27.

Ball, C. A., & Roma, A. (1994). Stochastic Volatility Option Pricing. *Journal of Financial and Quantitative Analysis*, *29*(4), 589–607. DOI:10.2307/2331111.

Bangur, P. (2020a). Strangle to resuscitate: Evidence from India. *Journal of Investment Strategies*, *9*(2). DOI: 10.21314/JOIS.2020.121.

Bangur, P. (2020b). Performance of strip option strategy on Indian capital market. *International Journal of Financial Services Management*, *10*(2), 128-137. DOI: 10.1504/IJFSM.2020.110225.

Bartoňová, M. (2012). Hedging of sales by zero-cost collar and its financial impact. *Journal of Competitiveness*. DOI: 10.7441/joc.2012.02.08.

Basson, L. J., Van den Berg, L., & Van Vuuren, G. (2018). Performance of two zero-cost derivative strategies under different market conditions. *Cogent Economics & Finance*, *6*(1), 1492893. DOI: 10.1080/23322039.2018.1492893.

Black, F., & Scholes, M. (1973). The Pricing of Options and Corporate Liabilities. *Journal of Political Economy*, *81*(3), 637–654. Available at: http://www.jstor.org/stable/1831029.

Bobriková, M. (2021). Price risk management in the wheat market using option strategies. *Economics of Agriculture, 68*(2), 449-461. DOI:10.5937/ekoPolj2102449B.

Bourghelle, D., Jawadi, F., & Rozin, P. (2021). Oil price volatility in the context of Covid-19. *International Economics*, *167*, 39-49. DOI: 10.1016/j.inteco.2021.05.001.

Buehler, Hans and Gonon, Lukas and Teichmann, Josef and Wood, Ben, Deep Hedging (February 8, 2018). Available at SSRN: https://ssrn.com/abstract=3120710.

Carr, P., & Wu, L. (2014). Static hedging of standard options. *Journal of Financial Econometrics*, *12*(1), 3-46. DOI:10.1093/jjfinec/nbs014.

Crépey, S. (2004). Delta-hedging vega risk?. *Quantitative Finance*, *4*(5), 559-579. DOI: 10.1080/14697680400008718.

Dewobroto, D., Febrian, E., Herwany, A., & Brahmana, R. K. (2010). The Best Stock Hedging Among Option Strategies. *Research Journal of Applied Sciences, 5*(6), 397-403. DOI: 10.3923/rjasci.2010.397.403.

Diaz, M., & Kwon, R. H. (2017). Optimization of covered call strategies. *Optimization Letters*, *11*, 1303-1317. DOI: 10.1007/s11590-016-1083-8.

Du, J., Jin, M., Kolm, P. N., Ritter, G., Wang, Y., & Zhang, B. (2020). Deep reinforcement learning for option replication and hedging. *The Journal of Financial Data Science*, *2*(4), 44-57. DOI: 10.3905/jfds.2020.1.045.

Figlewski, S., Chidambaran, N. K., & Kaplan, S. (1993). Evaluating the performance of the protective put strategy. *Financial Analysts Journal*, *49*(4), 46-56. Available at: https://www.jstor.org/stable/i404362.

Fullwood, J., James, J., & Marsh, I. W. (2021). Volatility and the cross-section of returns on FX options. *Journal of Financial Economics*, *141*(3), 1262-1284. DOI: 10.1016/j.jfineco.2021.04.030.

Guo, Y., Ma, F., Li, H., & Lai, X. (2022). Oil price volatility predictability based on global economic conditions. *International Review of Financial Analysis*, *82*, 102195. DOI: 10.1016/j.irfa.2022.102195.

Harčariková, M., & Šoltés, M. (2016). Risk Management in Energy Sector Using Short Call Ladder Strategy. *Montenegrin Journal of Economics, 12*(3), 39-54. DOI: 10.14254/1800-5845.2016/12-3/3.

Harčariková, M., & Šoltés, M. (2017). New hedging techniques in energy sector using barrier options. *Acta Montanistica Slovaca*, *22*(4).

Harčariková, M. (2018). Managing price risk in the corn market using option strategies. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 66*(3), 767-779. DOI: 10.11118/actaun201866030767.

Heston, S. L. (1993). A closed-form solution for options with stochastic volatility with applications to bond and currency options. *The review of financial studies*, 6(2), 327-343. Available at: https://www.jstor.org/stable/2962057.

Hull, J., & White, A. (2017). Optimal delta hedging for options. *Journal of Banking & Finance,* 82, 180-190. DOI: 10.1016/j.jbankfin.2017.05.006.

Charfeddine, L., & Barkat, K. (2020). Short-and long-run asymmetric effect of oil prices and oil and gas revenues on the real GDP and economic diversification in oil-dependent economy. *Energy Economics*, *86*, 104680. DOI: 10.1016/j.eneco.2020.104680.

Chatziantoniou, I., Filippidis, M., Filis, G., & Gabauer, D. (2021). A closer look into the global determinants of oil price volatility. *Energy Economics*, *95*, 105092. DOI: 10.1016/j.eneco.2020.105092.

Chen, A. S., & Leung, M. T. (2003). Option straddle trading: Financial performance and economic significance of direct profit forecast and conventional strategies. *Applied Economics Letters*, *10*(8), 493-498. DOI: 10.1080/1350485032000095375.

Israelov, R., & Klein, M. (2017). *Risk and return of equity index collar strategies*. Available at SSRN: https://ssrn.com/abstract=2704518.

Israelov, R., & Nielsen, L. N. (2015). Covered calls uncovered. *Financial Analysts Journal*, *71*(6), 44-57. Available at SSRN: https://ssrn.com/abstract=2444999.

Jebabli, I., Kouaissah, N., & Arouri, M. (2022). Volatility spillovers between stock and energy markets during crises: A comparative assessment between the 2008 global financial crisis and the COVID-19 pandemic crisis. *Finance Research Letters 46*. DOI: 10.1016/j.frl.2021.102363.

Jiang, Z., & Yoon, S. M. (2020). Dynamic co-movement between oil and stock markets in oil-importing and oil-exporting countries:

Two types of wavelet analysis. *Energy Economics*, *90*, 104835. DOI: 10.1016/j.eneco.2020.104835.

Kedžo, M. G., & Šego, B. (2021). The relative efficiency of option hedging strategies using the third-order stochastic dominance. *Computational management science*, *18*(4), 477-504. DOI: 10.1007/s10287-021-00401-z.

Łamasz, B., & Iwaszczuk, N. (2020). Crude oil option market parameters and their impact on the cost of hedging by long strap strategy. *International Journal of Energy Economics and Policy*, *10*(1), 471-480. Available at: https://www.econjournals.com/index.php/ijeep/article/view/8613.

Lee, R. W. (2005). Implied volatility: Statics, dynamics, and probabilistic interpretation. *Recent advances in applied probability*, 241-268. DOI: 10.1007/0-387-23394-6_11.

Liu, Y., Naktnasukanjn, N., Tamprasirt, A., & Rattanadamrongaksorn, T. (2024). Do crude oil, gold and the US dollar contribute to Bitcoin investment decisions? An ANN-DCC-GARCH approach. *Asian Journal of Economics and Banking*, *8*(1), 2-18. DOI: 10.1108/AJEB-10-2023-0106.

Lu, Q., Li, Y., Chai, J., & Wang, S. (2020). Crude oil price analysis and forecasting: A perspective of "new triangle". *Energy Economics*, *87*, 104721. DOI: 10.1016/j.eneco.2020.104721.

Mensi, W., Al Rababa'a, A. R., Vo, X. V., & Kang, S. H. (2021). Asymmetric spillover and network connectedness between crude oil, gold, and Chinese sector stock markets. *Energy Economics, 98*(2). DOI: 10.1016/j.eneco.2021.105262.

Merton, R. C. (1973). An intertemporal capital asset pricing model. *Econometrica: Journal of the Econometric Society*, 867-887. Available at: https://www.jstor.org/stable/1913811.

Mokni, K. (2020). Time-varying effect of oil price shocks on the stock market returns: Evidence from oil-importing and oil-exporting countries. *Energy Reports*, *6*, 605-619. DOI: 10.1016/j.egyr.2020.03.002.

Murshed, M., & Tanha, M. M. (2021). Oil price shocks and renewable energy transition: Empirical evidence from net oil-importing South Asian economies. *Energy, Ecology and Environment*, *6*(3), 183-203. DOI: 10.1007/s40974-020-00168-0.

Mugwagwa, T., Ramiah, V., Naughton, T., & Moosa, I. (2012). The efficiency of the buy-write strategy: Evidence from Australia. *Journal of International Financial Markets, Institutions and Money*, *22*(2), 305-328. DOI: 10.1016/j.intfin.2011.10.001.

Niblock, S. J., & Sinnewe, E. (2018). Are covered calls the right option for Australian investors?. *Studies in Economics and Finance*, *35*(2), 222-243. DOI: 10.1108/SEF-07-2016-0164.

Nonejad, N. (2020). A detailed look at crude oil price volatility prediction using macroeconomic variables. *Journal of Forecasting*, *39*(7), 1119-1141. DOI: 10.1002/for.2679.

Rusnáková, M. (2015). Commodity price risk management using option strategies. *Agricultural Economics, 61*(4), 149-157. DOI:10.17221/101/2014-AGRICECON.

Salisu, A. A., Vo, X. V., & Lawal, A. (2021). Hedging oil price risk with gold during COVID-19 pandemic. *Resources Policy 70.* DOI: 10.1016/j.resourpol.2020.101897.

Shivaprasad, S. P., Geetha, E., Raghavendra, K. L., & Rajeev, M. (2022). Are Options Trading Strategies Really Effective for Hedging in the Indian Derivatives Market?. *Cogent Economics & Finance*, *10*(1), 2111783. DOI: 10.1080/23322039.2022.2111783.

Stein, E. M., & Stein, J. C. (1991). Stock price distributions with stochastic volatility: an analytic approach. *The review of financial studies*, *4*(4), 727-752.

Taušer, J., & Čajka, R. (2014). Hedging techniques in commodity risk management. *Agricultural Economics, 60*(4), 174-182. DOI: 10.17221/120/2013-AGRICECON.

Thanekar, G. S., & Shaikh, Z. S. (2021). Hedging The Portfolio Using Options Strategies. *2021 7th International Conference on Advanced Computing and Communication Systems – ICACCS* India, 19-20 March, 2021. New Jersey, US: IEEE, 586-591. DOI: 10.1109/ICACCS51430.2021.9441986.

Vähämaa, S. (2004). Delta hedging with the smile. *Financial Markets and Portfolio Management*, *18*(3), 241-255. DOI: 10.1007/s11408-004-0302-y.

Wang, G., Sharma, P., Jain, V., Shukla, A., Shabbir, M. S., Tabash, M. I., & Chawla, C. (2022). The relationship among oil prices volatility, inflation rate, and sustainable economic growth: Evidence from top oil importer and exporter countries. *Resources Policy*, *77*, 102674. DOI: 10.1016/j.resourpol.2022.102674.

Xia, K., Yang, X., & Zhu, P. (2023). Delta hedging and volatility-price elasticity: A two-step approach. *Journal of Banking & Finance*, *153*, 106898. DOI: 10.1016/j.jbankfin.2023.106898.

Yang, S. (2023). Analysis on Hedging and Risk Management of Options and Futures. *Highlights in Business, Economics and Management*, *15*, 273-280. DOI: 10.54097/hbem.v15i.9456.

Učinak zaštite od cjenovnog rizika derivatima sirove nafte

Sažetak

Ovaj rad analizira zaštitu od rizika putem opcijskih strategija u svrhu ublažavanja nepovoljnih cjenovnih fluktuacija. Metodologija uključuje razvoj analitičkog okvira za određivanje gornje granice cijene kako bi se procijenio učinak upravljanja cjenovnim rizikom. Ovakav pristup omogućuje usporedbu različitih opcijskih strategija zaštite u različitim mogućim scenarijima kretanja cijena. Istraživanje je usmjereno na teorijske izvedenice primijenjene u tržištu sirove nafte kako bi se istražilo kako određeni parametri utječu na odabir optimalnih strategija zaštite. Osim toga, uspoređuju se ove strategije s onima predloženima u prethodnim istraživanjima. Rezultati nude preporuke za korištenje opcijskih strategija koje su u skladu s očekivanim budućim kretanjima cijena. Integracijom stvarnih primjena u zaštiti portfelja sirove nafte, ovaj rad nastoji povećati svoju praktičnu relevantnost. Ovo istraživanje popunjava prazninu u postojećem znanju o zaštiti od rizika korištenjem opcijskih strategija. Ograničenja se mogu pojaviti u pogledu generalizacije rezultata iz jedne varijable, tj. profitabilnosti.

Ključne riječi: energetsko tržište, zaštita od rizika, opcijske strategije, cjenovne fluktuacije