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Article

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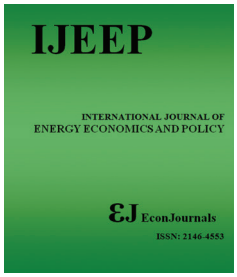

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WTI Crude Oil Options Market Prior to and During the COVID-19 Pandemic

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ABSTRACT

The COVID-19 pandemic has caused turbulence in many areas of the global economy. It also contributed to an increase in volatility on the energy commodities market. This spilled over into the derivatives market, particularly the crude oil futures market. The aim of the article is to compare the costs and effectiveness of using options on WTI oil from before and after the pandemic. The analyzes took into account the value of option premiums and final results obtained by buyers of call options from March 01, 2018 to April 14, 2022. The results showed that buyers of call options during the pandemic, despite paying much higher option premiums, experienced significantly higher payouts and rates of return. They were the highest for options with the longest expiry periods of 21-30 days. Research also showed that during the pandemic, options with strike prices set at a level higher than the price of oil on the contract date had particularly high rates of return, while the highest payout values were achieved by buyers of call options with low strike prices.

Keywords: Price Risk, Crude Oil, Options Market, Implied Volatility, COVID-19
JEL Classifications: G32, G110

1. INTRODUCTION

Prices are usually much more volatile on the commodities markets than those of stocks or indices listed on the world's largest stock exchanges. Rapid price fluctuations may be attributed to high susceptibility to geopolitical events, which may result, among others, in supply chain disruptions and affect both lead times as well as production and delivery costs. Most commodities are of strategic importance. At some stage, crude oil is crucial to the proper functioning of all sectors of the economy. It contributes directly or indirectly, often significantly, to the prices of almost all goods and services.

Spencer Dale, BP's chief economist, recently pointed out that the challenges and uncertainty facing global energy systems are at their greatest since the time of the energy shocks in the 1970 s (BP, 2022). Total world energy consumption in 2021 has surpassed pre-pandemic levels and continues to grow. These developments have significantly altered prospects for fossil fuels, including crude oil, especially in the EU, compounded by the war in Ukraine. The long-term impact on carbon emissions is difficult to forecast, given on one hand greater interest in developing renewable energy sources but on the other natural gas supply disruptions. A short-term alternative for some countries is coal, which has roughly twice the CO_2 emissions of natural gas per unit of energy. EU's plan to replace oil burning vehicles with electric ones will take many years, given that there are almost 300 million vehicles on EU's roads today (ACEA, 2022) and the vast majority of them are fueled by gasoline or diesel fuel. Both of which are currently refined from crude oil with only minor biofuel additions.

Crude oil price spikes are one of the numerous problems that the energy sector must currently grapple with. In the global economy, crude oil plays a crucial role in transportation and production processes. Given its significance, it has been traded on financial markets since the 1980 s. Both private and institutional investors,

that is those who invest on behalf of their members or clients, can invest in crude oil and refined products just like in stocks, debt instruments, currency pairs or other commodities, such as gold.

Instruments are available on the financial markets to hedge against oil price volatility. These include derivatives that enable future deliveries to be settled at a price fixed at the time the contract is concluded. Options are one of the main types of derivatives. They are traded on the world's largest commodity exchanges. Due to their asymmetric risk distribution, these instruments play an important role in the process of managing price risk, including the risk of changes in oil prices. However, the latest research shows that the COVID-19 pandemic has had a large impact on option premiums, which may result in an increase in the costs of using these types of securities (Li et al., 2022).

The aim of this article is to investigate the changes in the market for call options on WTI oil following the outbreak of the pandemic. The analysis is based on market parameters of options listed on the CME Group stock exchange during the period from March 01, 2018 to April 14, 2022. In March 2020, many economies announced lockdowns, which resulted in a significant economic slowdown in the following months. Many governments introduced aid for companies whose activities were suspended or significantly reduced during the pandemic. Unexpected turbulences in the economy and quick decisions by the rulers were one of the main reasons for the increase in oil price volatility and undoubtedly also changed the futures market (also known as "paper market") for this commodity as well. The authors of the study therefore attempted to compare the state of this market-with special emphasis on options – before and after the outbreak of the pandemic. The empirical part of the article focuses primarily on the analysis of market parameters of options such as option premium and implied volatility. A detailed analysis of the end results (payoffs) for buyers of American call options was also carried out. Options were classified according to two main criteria: time to expiration date and exercise price.

The remainder of the article is organized as follows. Section 2 contains the literature review. Section 3 presents the source data and research methodology, along with indicators for assessing the effectiveness of long positions in call options. Section 4 is a preliminary data analysis WTI oil prices and implied volatility. Results are shown in Section 5. The article ends with Conclusions from the research and analyses that was conducted.

2. LITERATURE REVIEW

COVID-19 is an infectious disease transmitted by viruses-a strain that first appeared in Wuhan, China in late 2019, and the following year began to spread rapidly throughout the world (Phan and Narayan, 2020; Farid et al., 2021). The World Health Organization (WHO) quickly labeled the coronavirus outbreak as a pandemic based on tracking the daily number of COVID-19 deaths and illnesses.

In addition to being a tragedy, that it is undoubtedly based on the loss of lives of millions of people, COVID-19 has also turned out to be a major threat to the global economy (Mensi et al., 2020). The global economic crisis triggered by the virus has caused enormous economic losses in many industries and even on the scale of entire countries (Alfaro et al., 2020; Baker et al., 2020; Ding et al., 2020). The crisis was closely related to the actions of governments around the world to limit economic activity to prevent the spread of the virus (Yang and Deng, 2021). New waves of the disease also resulted in increased uncertainty among people, moved through investors, among others, to the financial markets (Altig et al., 2020; Ashraf, 2020; Salisu and Akanni, 2020, Baek and Lee, 2021; Szczygielski et al., 2022).

Numerous economic restrictions that were introduced, and the consequent production slowdown, significantly reduced the demand for crude oil in 2020. Oil prices reacted sharply to the introduction of the first lockdowns. Qin et al. (2020) showed that the first phase of the COVID-19 pandemic caused a reduction in oil demand, which led to a drop in oil prices. Similar conclusions were reached by Gil-Alana and Monge (2020), who noted that COVID-19 made the oil market inefficient, making oil prices unpredictable. Moreover, recent studies confirm that the commodity market, especially the oil market, is strongly related to other financial markets and has a significant impact on the condition of the global economy (Liang et al., 2020; Da Silva Souza and Fry-McKibbin, 2021).

Many scientific studies were conducted in the years 2020-2022, which studied the impact of COVID-19 on various sectors of the economy and the condition of companies for which the level of crude oil prices is especially important to the profitability of their operations. Akhtaruzzaman et al. showed that companies active in extraction and supply of crude oil benefit from increases in the price of this commodity, while manufacturing companies as well as the financial sector react negatively (Akhtaruzzaman et al., 2020). Fu and Shen analyzed the impact of COVID-19 on the performance of companies in the energy industry and found that there was a significant negative impact (Fu and Shen, 2020). The energy industry seems to be viewed by some analysts as being the most affected by the coronavirus pandemic (Nguyen, 2020; Ramelli and Wagner, 2020). Whereas, at least by some measures, the impact on other industries, such as the tourist and aviation industries was far greater.

In turn, Huang and Liu investigated the impact of the COVID-19 pandemic on the risk of a crash in Chinese energy companies' stock prices (Huang and Liu, 2021). They showed, among other things, that the risk of a sharp drop in share prices of these companies decreased significantly after lockdowns were lifted in that country. During the period being considered, the risk of a stock market crash was less severe for state-owned enterprises (SOE) than for non-SOE enterprises. This is not surprising given the history of favorable treatment of SOEs in China. Babu et al. (2022) focused on the impact of COVID-19 on stock prices of India's publicly traded energy companies. They showed that in some enterprises, volatility remained at a much higher level during the COVID-19 pandemic relative to the time before the pandemic.

Research interest on the impact of the coronavirus pandemic on both the broadly understood financial markets and the oil market

has been strong over the last 2 years. Studies focused primarily on the impact of the pandemic on stock prices and stock indices (Al-Awadhi et al., 2020; Ali et al., 2020; Nadeem, 2022; Baig et al., 2021; Akbulaev et al., 2022; Alexandri et al., 2022) On the other hand, fewer studies analyzed the impact of COVID-19 on the commodity derivatives market, which is important from the perspective of companies bearing the risk of oil price changes. It is also worth emphasizing that with the rapid development of the commodity derivatives market, the relationships between the commodities market and other markets become more and more complex, thus constituting a significant source of risk that cannot be ignored in the economic system (Chen et al., 2022). Commodity options in particular are one of the most useful risk management tools in the current capital market and also an important part of the commodity market (Christensen et al., 2010).

The work of Chen et al. (2022) is one of the few articles on the subject of changes taking place in the commodity options market in recent months. The authors of that article analyzed the impact of COVID-19 on the volatility of the commodity options market. They focused on intraday volatility of 16 commodity options contracts on the Chinese commodity options market over the period 2019-2021. Their research showed that after the pandemic diminished in severity, the volatility of agricultural commodities remained at a much higher level than before the outbreak of the pandemic. In contrast, the impact on the volatility of options for petrochemicals, ores, and metals was negligible.

Our article expands existing research by analyzing the changes that have occurred on the WTI crude oil options market. We focused on call options with different strike prices, analyzing both the value of option premiums and the level of end results (payoffs) that the buyer could expect before and after the outbreak of the coronavirus pandemic. Studies conducted so far on the volatility of options, which is important from the perspective of the risk assessment of both the underlying instrument and the options market itself, have not analyzed the effectiveness of hedging the price risk using these instruments.

3. DATA AND METHODOLOGY

The empirical part of the paper focuses on WTI prices and WTI crude oil American options listed on the NYMEX in the period from March 1, 2018 to April 14, 2022. Options with an expiry period of up to 30 days were considered. The authors selected American options for analysis based on their high liquidity and large volume. As a result, the options' strike prices are very diversified. Every day, from several dozen to even several hundred different strike prices are available (these prices vary by 0.5 USD/barrel). This great flexibility in determining the price at which the option will be settled in the future results in greater opportunities to accommodate buyers' specific risk appetites or aversion in the current market situation and their expectations for the near future. The flexibility of American options is reflected in the fact that they can be exercised at any time before the expiry date. This means that investors can instantly react and close their positions before the expiry date (European options do not allow this).

Data for analysis was obtained from QuikStrike-an options analytics platform available on the CME Group's website via Bantix Technologies LLC (BANTIX, 2022). The time period in question was divided into two sub-periods. The first one covers the period from March 1, 2018 to February 29, 2020 and should be viewed as "the period before the outbreak of the coronavirus pandemic." The next 2 years (from March 1, 2020 to April 14.2022) were defined as a period of the pandemic developing in the world, which caused significant turmoil in many economic sectors.

As mentioned previously, the subject of the research were American call options on the price of WTI crude oil with the time to maturity of up to 30 days. Options with different strike prices are available in the QuikStrike database, which have different levels of option premiums that the buyer of such options has to pay. Call options used in the research were divided according to two criteria. The first relates to the number of days remaining until the option expires, and the second relates to the strike price. A brief description of each of the classifications is presented below.

1. Days left until option expiry:
   [1] Category 1-10d: Call options with 1-10 days until expiry
   [2] Category 11-20d: Call options with 11-20 days until expiry
   [3] Category 21-30d: Call options with 21-30 days until expiry.
2. Option exercise price depending on the at the money (ATM) option exercise price on the day the position is opened, shown as K_0:

- 0.90: Call options with an exercise price (K) in the range of 90-91% of the K_0 ($K \in [0.90K_0;0.91K_0)$);
- 0.91: Call options with an exercise price in the range of 91-92% of the K_0 ($K \in [0.91K_0;0.92K_0)$);
- 0.92: Call options with an exercise price in the range of 92-93% of the K_0; ($K \in [0.92K_0;0.93K_0)$);
- 0.93: Call options with an exercise price in the range of 93-94% of the K_0 ($K \in [0.93K_0;0.94K_0)$);
- 0.94: Call options with an exercise price in the range of 94-95% of the K_0 ($K \in [0.94K_0;0.95K_0)$);
- 0.95: Call options with an exercise price in the range of 95-96% of the K_0 ($K \in [0.95K_0;0.96K_0)$);
- 0.96: Call options with an exercise price in the range of 96-97% of the K_0 ($K \in [0.96K_0;0.97K_0)$);
- 0.97: Call options with an exercise price in the range of 97-98% of the K_0 ($K \in [0.97K_0;0.98K_0)$);
- 0.98: Call options with an exercise price in the range of 98-99% of the K_0 ($K \in [0.98K_0;0.99K_0)$);
- 0.99: Call options with an exercise price in the range of 99-100% of the K_0 ($K \in [0.99K_0;K_0)$);
- 1: ATM call options (options with an exercise price equals K_0);
- 1.01: Call options with an exercise price in the range of 100-101% of the K_0 ($K \in (K_0;1.01K_0)$);
- 1.02: Call options with an exercise price in the range of 101-102% of the K_0 ($K \in [1.01K_0;1.02K_0)$);
- 1.03: Call options with an exercise price in the range of 102-103% of the K_0 ($K \in [1.02K_0;1.03K_0)$);

- 1.04: Call options with an exercise price in the range of 103-104% of the K_0 ($K \in [1.03K_0;1.04K_0)$);
- 1.05: Call options with an exercise price in the range of 104-105% of the K_0 ($K \in [1.04K_0;1.05K_0)$);
- 1.06: Call options with an exercise price in the range of 105-106% of the K_0 ($K \in [1.05K_0;1.06K_0)$);
- 1.07: Call options with an exercise price in the range of 106-107% of the K_0 ($K \in [1.06K_0;1.07K_0)$);
- 1.08: Call options with an exercise price in the range of 107-108% of the K_0 ($K \in [1.07K_0;1.08K_0)$);
- 1.09: Call options with an exercise price in the range of 108-109% of the K_0 ($K \in [1.08K_0;1.09K_0)$);
- 1.1: Call options with an exercise price in the range of 109-110% of the K_0 ($K \in [1.09K_0;1.1K_0)$).

Options from the 0.90-0.99 category were in the money (ITM) on the day the position was opened. This means that their strike price was lower than the strike price of an ATM option (category 1), and therefore their immediate exercise would guarantee a positive payout (payout >0) to the option buyer. In turn, category 1.01-1.1 options are out of the money (OTM) because their execution on the purchase date would mean a zero payout for the buyer.

Analysis of data began with comparing the descriptive statistics of WTI crude oil prices and the level of ATM options' implied volatility before and after the outbreak of the COVID-19 pandemic. Next, the levels of implied volatility for option classes defined above were compared. This parameter is particularly important from the perspective of shaping the option premium. Therefore the analysis of its value is essential from the perspective of active participants in ommodity options market.

The empirical part of the work focuses on the values of option premiums in groups of options. The following indicator was defined for this purpose:

$$Premium\,level\,(K;t) = \frac{c(K;t)}{ATM}100\% \quad (1)$$

Where *c (K;t)* is the average call option premium for a given option category (K-category based on price, t-category based time to expiry) and ATM is the strike price of an ATM option.

The next part of the analysis focused on the value of the final results for the buyer of a call option. Three indicators were used to measure effectiveness.

- Proportion of exercising long positions in call options during the analyzed period:

$$Realized(K;t) = \frac{L(K;t)}{S(K;t)}100\% \quad (2)$$

Where *L (K;t)* is the number of long positions in call option in a given option category (*K*- category based on price, *t*-category based on expiry date) that were executed and *S (K;t)* is the total number of long positions in a given option category.

- Proportion of long call options being profitably exercised during the period being analyzed:

$$Realized_{+}(K;t) = \frac{L_{+}(K;t)}{S(K;t)}100\% \quad (3)$$

Where L_{+} *(K;t)* is the number of long position in call option in a given option category that were profitably executed.

- Result as a percentage of invested capital (option premium value)

$$Result(K;t) = \frac{payoff\,(K;t)}{c(K;t)}100\% \quad (4)$$

Where *payoff (K;t)* is the final result for the buyer of an option in a given option category, expressed by the formula (F is the price of the underlying on the option exercise date):

$$payoff\,(K;t) = max\{F-K;0\} - c(K) \quad (5)$$

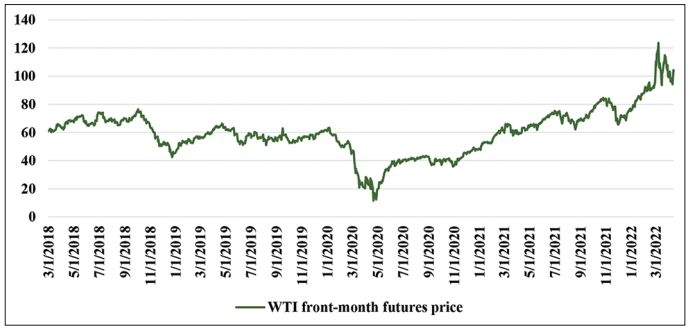
Statistics for these results broken down into before and after COVID-19.

4. PRELIMINARY ANALYSIS: WTI PRICE AND IMPLIED VOLATILITY BEFORE AND DURING COVID-19

Two values were analyzed in the first part of the study: WTI front month futures prices and implied volatility of ATM WTI Crude Oil options. Both oil futures prices and implied volatility values applied to contracts with maturity not exceeding 30 days (hence the term "front month futures"). ATM options are options whose strike price was set at the level of the WTI futures price on the day the position was opened (rounded to 0.5 USD/barrel). The value of implied volatility is calculated directly from a transformation of formulae for calculation of the theoretical value of an option provided that the actual (market) price of the option is known. One of the most commonly used models for this purpose is the Black-Scholes model (1973) which uses the Black option pricing formula for commodity options [3]. The values of WTI crude oil futures prices and the volatility of ATM options are presented in Figures 1 and 2. Descriptive statistics for these values are presented in Tables 1 and 2.

Prices initially decreased at the onset of the pandemic due to diminished demand (Figure 1). However, the continued decline in prices contributed to a gradual decrease in supply combined with a

Figure 1: WTI front month futures prices in USD/barrel from 1.03.2018 to 14.04.2022



more sudden drop as the pandemic impacted almost all aspects of crude oil production and refining processes. This, in turn led to a spike in volatility and prices exhibited an upward trend ever since.

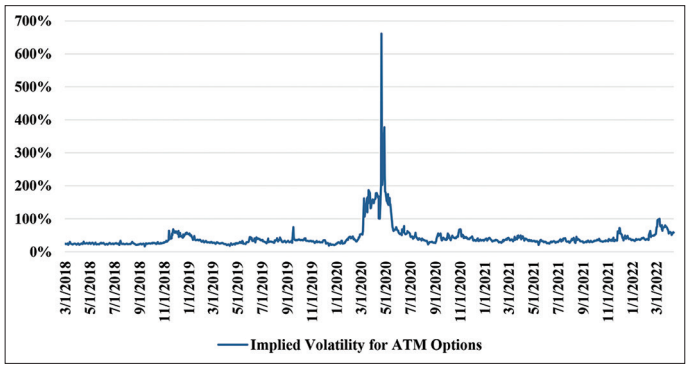
The arithmetic means and medians are similar prior to and during the pandemic. However, the remaining values are significantly different. The period after the outbreak of the pandemic was characterized by high price volatility, and the downward (during the initial months of the pandemic) and upward price trends were much more intense. As a result, the measures of dispersion (standard deviation and coefficient of variation) in the period after March 1, 2020 were over 3 times greater than before that date.

Large crude oil price fluctuations after March 01, 2020 resulted in significantly higher levels of implied volatility of options. The median implied volatility is 35% higher, the coefficient of variation is over there times higher, skewness and kurtosis are significantly larger implying significant asymmetry, which may be observed as a very high maximum value and heavy tails.

Since the empirical part of the study also analyzed non-ATM options, the preliminary analyses therefore included implied volatility values for each option category. Implied volatility values were compared before and after the outbreak of the COVID-19 pandemic. Average values of implied volatility for each call option class (Table 3). These results are shown in Figure 3.

The data shows that the biggest increases in implied volatility after the outbreak of COVID-19 occurred for ATM options. During the pandemic, the implied volatility of ATM options for all time categories (1-10d, 11-20d and 21-30d) was higher by approx. 70%

Figure 2: Implied volatility of ATM options from 1.03.2018 to 14.04.2022



(Figure 3), which resulted in higher option premiums (analyzed later in the article). In the case of options with other strike prices, higher levels of volatility were observed since the outbreak of the pandemic (after March 01, 2020), but these differences were not as pronounced as in the case of ATM options and depended much more on the expiry date of the option (the shorter the time to expiry, the smaller the increase in volatility).

5. RESULTS

5.1. Option Premiums Analysis

This part of the study analyzes the value of option premiums for call options, different ATM options, in the period before and after the outbreak of the pandemic. This analysis is important for the decisions the option buyer makes to hedge against oil price increases.

Average call option premiums are negatively correlated with time to expiry since. In general, less variation in price is expected in the short term. This translates into a smaller potential benefit from buying an option. Average option prices after the pandemic started (shown as solid lines on the Figure 4) increased compared to the period before the pandemic (columns). This is likely due to higher option price volatility, which will be explored in subsequent analyses. As expected, ITM options are most expensive and average prices decrease as options become more OTM, as expressed by the strike price category on the horizontal axis.

An analysis of the changes in the level of option premiums (Table 4 and Figure 4) shows that their average values after the outbreak of the pandemic increased by approx. 50%, and this increase was the highest for options with the shortest time to expiry. For ITM options, the differences in premiums between the two analyzed periods were much smaller (20-80%) than for OTM options (90-400%). This is especially evident in the case of options with the highest strike price, whose price during the pandemic was up to 4 times larger than pre-pandemic prices. The premium for strike price category 1.01, i.e. for options with a strike price up to 1% higher than the strike price of ATM options, was also remarkable. Option premiums in this case were on average 10-18% higher than ATM option premiums, which is a reversal of the obvious relationship for call options: the higher the strike price, the lower the option premium. This state of the market suggests that buyers of call options during the pandemic were more willing to choose higher strike prices when the probability of an increase

Table 1: Descriptive statistics of WTI front-month futures prices

COVID category	Num. of obs.	Mean	Median	Min	Max	Lower quartile	Upper quartile	Standard deviation	Skewness	Kurtosis
0	498	60.32	59.12	42.53	76.41	54.79	66.43	7.03	0.17	−0.83
1	536	59.48	61.56	11.57	123.70	40.97	73.30	22.13	0.22	−0.45

Table 2: Descriptive statistics of implied volatility for ATM options

COVID category	Num. of obs.	Mean	Median	Min	Max	Lower quartile	Upper quartile	Standard deviation	Skewness	Kurtosis
0	498	30.87	28.27	16.26	74.65	24.74	34.73	8.92	1.67	3.17
1	536	53.86	38.34	20.70	661.48	33.33	52.63	48.62	5.74	52.79

Table 3: Descriptive statistics of implied volatility for different classes of call options

Strike price category (K)	Time category (t)					
	1-10 days		11-20 days		21-30 days	
	COVID category		COVID category		COVID category	
Strike price category (K)	0 (%)	1 (%)	0 (%)	1 (%)	0 (%)	1 (%)
0.9	46.76	50.28	37.37	55.20	33.43	50.28
0.91	43.43	50.65	35.75	51.09	33.08	50.65
0.92	40.66	50.17	35.14	55.17	32.93	50.17
0.93	39.27	47.41	34.42	49.85	31.84	47.41
0.94	37.62	45.83	33.51	49.47	31.27	45.83
0.95	35.98	48.63	32.59	48.46	30.78	48.63
0.96	34.73	46.45	32.24	49.98	30.47	46.45
0.97	32.62	45.02	31.15	48.50	29.59	45.02
0.98	32.67	43.89	31.94	44.84	30.51	43.89
0.99	31.58	40.64	30.39	43.28	29.48	40.64
1	31.28	52.79	31.36	54.38	30.02	52.79
1.01	30.58	40.15	29.68	42.74	28.87	40.15
1.02	31.02	42.75	30.84	43.83	29.66	42.75
1.03	30.40	42.98	29.60	45.63	28.45	42.98
1.04	31.85	43.47	30.03	45.03	28.80	43.47
1.05	32.05	44.96	29.71	45.49	28.64	44.96
1.06	32.85	41.78	29.91	45.13	28.62	41.78
1.07	33.89	42.30	30.50	43.50	29.03	42.30
1.08	35.32	43.93	30.60	46.70	29.36	43.93
1.09	36.74	43.73	30.89	44.87	29.28	43.73
1.1	40.07	42.56	31.85	46.72	29.18	42.56
All	34.39	45.47	31.93	47.81	30.19	45.47

Table 4: Average option premiums (USD/b)

Strike price category (K)	Time category (t)					
	1-10 days		11-20 days		21-30 days	
	COVID category		COVID category		COVID category	
Strike price category (K)	0	1	0	1	0	1
0.9	5.45	6.66	5.97	7.10	6.16	7.31
0.91	5.03	6.23	5.45	6.50	5.60	6.75
0.92	4.57	5.43	4.85	5.91	5.07	6.20
0.93	4.03	4.85	4.34	5.46	4.58	5.71
0.94	3.50	4.45	3.84	4.94	4.08	5.40
0.95	2.97	3.72	3.32	4.40	3.60	4.78
0.96	2.41	3.09	2.85	3.95	3.16	4.31
0.97	1.92	2.58	2.44	3.36	2.77	3.84
0.98	1.49	2.10	2.06	2.99	2.42	3.47
0.99	1.14	2.04	1.74	3.18	2.11	3.60
1	0.86	1.37	1.50	2.24	1.87	2.72
1.01	0.62	1.51	1.22	2.63	1.60	3.07
1.02	0.47	1.09	1.06	1.99	1.42	2.49
1.03	0.32	0.91	0.84	1.68	1.17	2.17
1.04	0.23	0.69	0.66	1.54	0.98	1.97
1.05	0.17	0.64	0.52	1.32	0.81	1.72
1.06	0.12	0.57	0.41	1.13	0.67	1.60
1.07	0.11	0.49	0.33	1.00	0.56	1.36
1.08	0.09	0.44	0.25	0.88	0.47	1.24
1.09	0.08	0.44	0.21	0.75	0.38	1.08
1.1	0.08	0.41	0.17	0.72	0.30	0.95
All	1.59	2.36	2.13	3.05	2.40	3.44

in the price of WTI oil was higher than its decrease. This was especially the case when national economies began to open up after the lockdowns, which was a strong signal of rising oil prices.

In addition to comparing the average values of option premiums, the authors also decided to examine the fluctuations of these values. Figure 5 shows the standard deviations of premiums for all call option categories. Deviations from the pre-pandemic average usually did not exceed 0.5 USD/b in each category. On the other hand, the pandemic resulted in much higher standard deviations, which were several to even more than an order of magnitude higher. It is also worth noting that for options with the lowest strike prices (strike price categories 0.90, 0.91 and 0.92), time to expiry did not significantly affect the standard deviations in each of the analyzed periods. Along with the increase in the option strike prices, standard deviations showed a downward trend, options with the shortest time to expiry with declined the fastest.

The last stage of option premiums analysis dealt with *Premium levels* (K;t) (Formula [1]). The *Premium level* indicator of the cost of an option relative to the exercise price is meant to provide an option price in relative terms. On average, relative option prices increase by 29%, 30% and 35% for the 1-10 days, 11-20 days and 21-30 days categories respectively (Table 5 and Figure 6). Yet again increases for individual strike price categories were much larger-the relative cost of ATM options increased by 71-72%. The largest relative price increases were for OTM options. This is in accordance with expectations: given higher volatility, exercising OTM options becomes more likely so their prices increase. This rise in relative price is significant-up to 3.5 fold in the case of the 1.09 strike price category for the period of 1-10 days.

5.2. Analysis of the Effectiveness of Long Positions in Call Options

In this part of the study, a detailed analysis of indicators was made, showing how the final results for buyers of call options with different strike prices (21 categories) and different exercise dates (3 categories) differ. The analyzes included a ratio showing the proportion of option being exercised (*Realized* [K;t]) and exercised with profit ($Realized_{+}$[K;t]), payoff values and ratios of the payoff values to ATM option exercise prices (*Result* [K;t]).

It was assumed, that options were realized (exercised) whenever they had value (positive payout), even though the option premium may have exceeded the option price resulting in a net loss. This aspect is explored in the Table 6 and Figure 7. On average, the *Realized* value was 23%, 36% and 57% greater during COVID for the 1-10 days, 21-20 days and 21-30 days categories respectively. The results also show a much higher proportion of ATM option executions during the pandemic. Before the outbreak of the pandemic, every second option of this type was exercised, while after the outbreak of the pandemic, they were exercised in more often than in 2/3 of cases. Again, similarly to the Premium level indicator, the differences for Realized value were most striking for OTM options-they increased 3.56 fold (when defined, i.e. "infinite" increases from 0% were not counted, so the actual number is higher). The largest increase for OTM options is 10.7 fold in the 1.1 strike price category for 21-30 days. In this category, every third call option was exercised, which means that in 1/3 of cases, the price of WTI oil on the option expiry date was at least 10% higher than the price on the day of opening the option position.

Figure 3: Percent change in implied volatility after COVID-19 pandemic outbreak

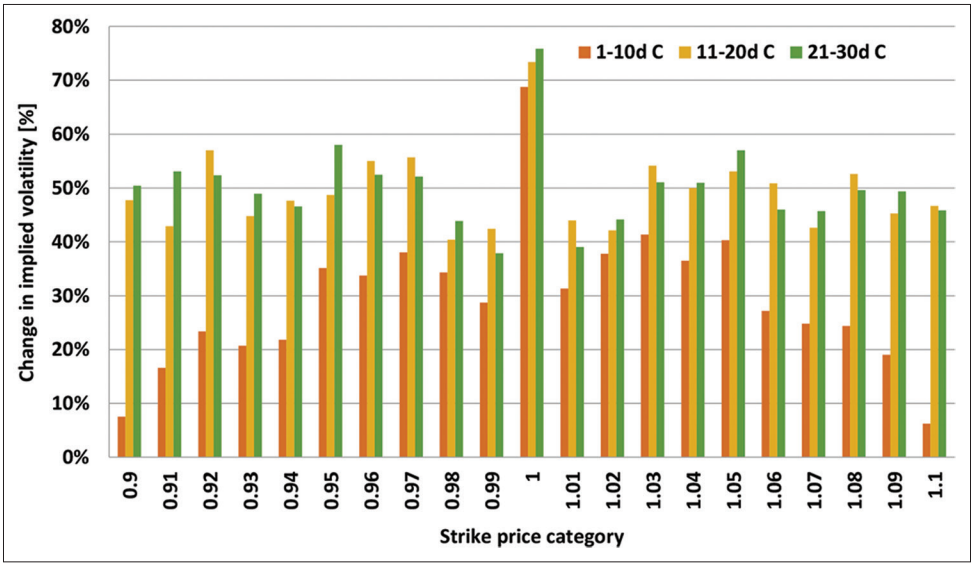


Figure 4: Average option premiums (USD/b)

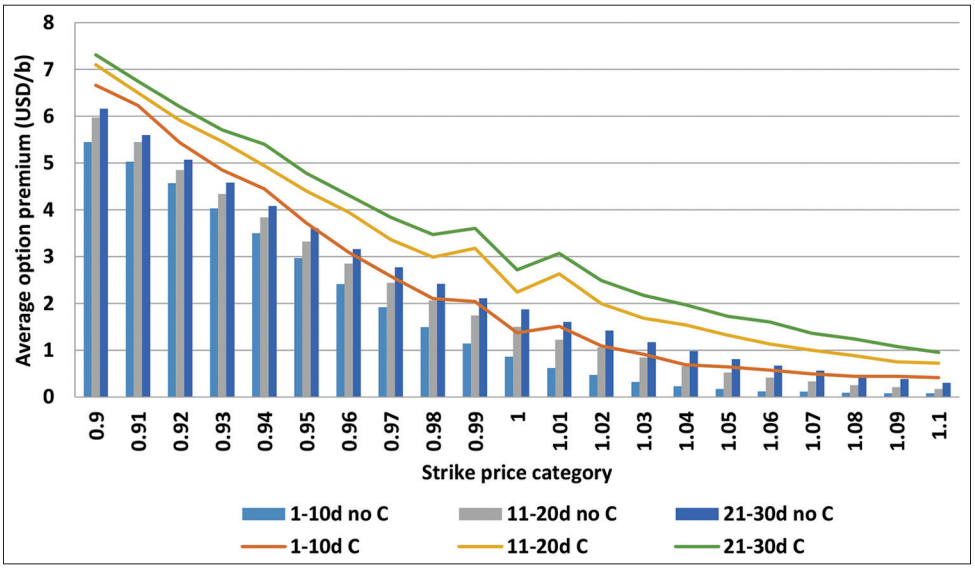
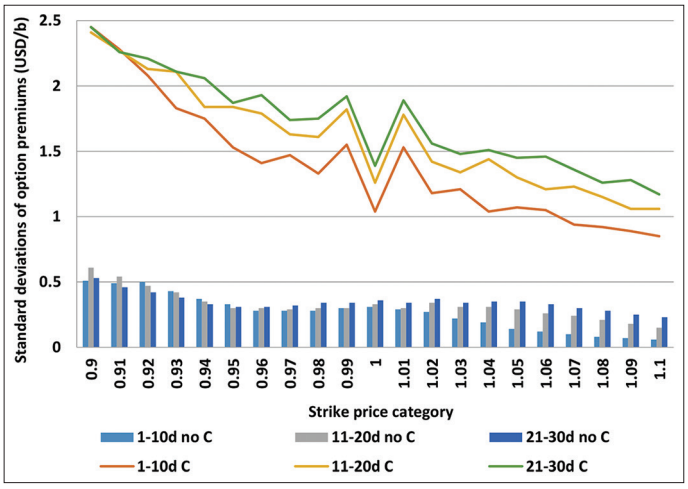


Figure 5: Standard deviation of option premiums (USD/b)



As explained previously the *Realized*$_+$ indicator looks only at options whose exercise resulted in net profit, i.e. the payout was greater than the option premium (Formula [3]). On average, the *Realized*$_+$ value was 50%, 68% and 98% greater during COVID for the 1-10 days, 21-20 days and 21-30 days categories respectively. Before the outbreak of the pandemic, about 2/3 of ATM options were loss-making for their buyers, whereas during the pandemic more than half of options of this type made a profit. A significant increase in the proportion of exercising call options with a profit can also be seen in the case of ITM options with a longer exercise period (in the 11-30 days category, the *Realized* + value was 55-69%), as well as in all categories of OTM options. Options with a strike price approx. 10% higher than the price of WTI oil on the day of opening the position, brought profit to their buyers in 1/3 of the cases (Table 7 and Figure 8).

The difference in *payoff* values from before COVID to after COVID is the most striking among all analyzed indicators. Average payoff for 1-10 days, 21-20 days and 21-30 days categories all turned from negative to positive values, i.e. from losses to profits (Table 8 and Figure 9). The greatest increases are for ITM

Table 5: Average value of option premiums

Strike price category (K)	Time category (t)					
	1-10 days		11-20 days		21-30 days	
	COVID category		COVID category		COVID category	
Strike price category (K)	0 (%)	1 (%)	0 (%)	1 (%)	0 (%)	1 (%)
0.9	9.67	9.99	9.88	10.72	10.07	11.26
0.91	8.72	9.17	8.92	9.69	9.19	10.45
0.92	7.71	8.10	8.01	9.18	8.38	9.72
0.93	6.76	7.23	7.14	8.03	7.49	8.77
0.94	5.81	6.19	6.32	7.33	6.68	7.99
0.95	4.90	5.58	5.48%	6.58	5.93	7.57
0.96	4.01	4.51	4.75	6.01	5.24	6.76
0.97	3.15	3.89	4.00	5.30	4.52	5.98
0.98	2.51	3.07	3.49	4.40	4.07	5.34
0.99	1.93	2.46	2.90	3.90	3.52	4.60
1	1.47	2.53	2.57	4.39	3.16	5.44
1.01	1.05	1.74	2.04	3.17	2.65	3.86
1.02	0.80	1.59	1.82	2.92	2.41	3.84
1.03	0.53	1.38	1.41	2.68	1.93%	3.43
1.04	0.39	0.97	1.14	2.25%	1.66	3.12
1.05	0.29	1.01	0.90	2.05	1.37	2.90
1.06	0.22	0.73	0.72	1.74	1.13	2.32
1.07	0.18	0.77	0.58	1.39	0.96	2.13
1.08	0.16	0.61	0.45	1.44	0.81	2.07
1.09	0.15	0.66	0.37	1.16	0.65	1.80
1.1	0.15	0.57	0.31	1.09	0.53	1.57
All	2.68	3.46	3.54	4.61	3.97	5.35

Table 6: *Realized* value for different call option categories

Strike price category (K)	Time category (t)					
	1-10 days		11-20 days		21-30 days	
	COVID category		COVID category		COVID category	
Strike price category (K)	0 (%)	1 (%)	0 (%)	1 (%)	0 (%)	1 (%)
0.9	98.59	94.08	91.91	95.22	86.30	96.58
0.91	95.10	94.44	91.75	93.65	81.64	92.86
0.92	93.53	94.44	86.77	94.17	77.67	93.61
0.93	91.89	94.59	79.43	90.16	74.06	88.48
0.94	90,50	93.40	77.01	91.58%	71.83	87.05
0.95	83.84	92.04	68.51	85.64	62.50	85.12
0.96	85.05	90.83	70.62	84.16%	61,03	81. 0.82
0.97	74.76	85.96	60.11	77,56	52.07	79.06
0.98	70.69	81.82	58.33	75.38	49.42	72.90
0.99	63.53%	71.77	52.78	69.81	46.39%	70.94
1	52.60	67.03	50.33	72.56	46.51	72.19
1.01	38.69	58.54	40.56	66.98	42.07%	66.67
1.02	25.43	55.45	36.77	65.26	41.86	65.42
1.03	12.32	38.72	30.69	56.67	33.18	63.25
1.04	7.98	30.53	26.44	48.96%	32.31	58.53
1.05	6.22	25.35	19.44	41.58	22.45	56.90
1.06	4.02	26.21	12.63	44.56	18.89	56.31
1.07	1.41	13.02	9.09	29.29%	13.21	47.93
1.08	3.28	9.95	7.57	21.43	9.22	46.76
1.09	0.00	9.78	4.15	18.59	5.80	40.09
1.1	0.00	5.30	3.80	15.46	3.33	35.51
All	48.15	59.16	46.78	63.55	44.41	69.56

Table 7: *Realized*$_+$ value for different call option categories

Strike price category (K)	Time category (t)					
	1-10 days		11-20 days		21-30 days	
	COVID category		COVID category		COVID category	
Strike price category (K)	0 (%)	1 (%)	0 (%)	1 (%)	0 (%)	1 (%)
0.9	61.97	63.91	46.24	68.90	43.38	66.24
0.91	60.78	65.56	45.36	65.61	44.93	66.52
0.92	57.55	66.16	46.03	67.48	40.29	65.75
0.93	48.65	60.81	41.71	63.73	41.98	61.75
0.94	49.16	67.51	43.32	68.42	42.25	64.77
0.95	48.99	60.62	38.12	58.51	39.50	62.81
0.96	48.45	61.14	40.11	61.39	44.10	60.91
0.97	42.38	56.17	36.70	57.07	37.33	60.26
0.98	44.25	59.55	39.10	58.97	38.95	55.61
0.99	37.65	54.84	36.11	54.72	33.13	59.83
1	32.95	52.43	35.29	56.71	31.40	55.08
1.01	22.02	47.15	27.97	50.00	29.27	58.97
1.02	14.45	43.64	27.74	50.53%	29.07	51.87
1.03	9.95	32.34	21.69	42.86	21.66	52.14
1.04	6.91	25.66	21.84	39.58	21.54	48.39
1.05	3.11	21.20	13.33	31.05	15.31	50.86
1.06	2.87	23.30	10.53	31.09	14.75%	47.57
1.07	1.41	11.63	7.95	19.19	8.02	41.94
1.08	1.64	8.90%	4.86	17.86%	5.34	39.35
1.09	0.00	8.70	3.63%	17.09	3.38	34.36
1.1	0.00	5.30	3.80	13.40	3.33	31.31
All	28.50	42.81	28.06%	47.10	27.86	53.92

Table 8: Average *payoff* values

Strike price category (K)	Time category (t)					
	1-10 days		11-20 days		21-30 days	
	COVID category		COVID category		COVID category	
Strike price category (K)	0	1	0	1	0	1
0.9	0.22	0.98	−0.64	1.38	−0.97	2.46
0.91	−0.06	1.00	−0.71	0.91	−0.82	2.46
0.92	−0.29	0.96	−0.56	1.21	−1.09	2.29
0.93	−0.37	0.81	−0.80	0.72	−1.04	2.01
0.94	−0.36	1.06	−0.59	1.23	−0.82	1.95
0.95	−0.44	0.62	−0.63	0.42	−0.94	2.15
0.96	−0.31	0.81	−0.42	0.90	−0.61	1.62
0.97	−0.37	0.50	−0.53	0.48	−0.80	1.97
0.98	−0.23	0.66	−0.34	0.69	−0.53	1.42
0.99	−0.25	0.35	−0.43	0.19	−0.65	1.75
1	−0.22	0.37	−0.27	0.73	−0.45	1.46
1.01	−0.27	0.18	−0.41	0.03	−0.58	1.58
1.02	−0.21	0.30	−0.26	0.27	−0.42	1.15
1.03	−0.19	0.08	−0.29	0.05	−0.49	1.38
1.04	−0.14	0.02	−0.23	−0.05	−0.41	0.90
1.05	−0.12	−0.05	−0.23	−0.19	−0.41	1.01
1.06	−0.10	−0.12	−0.20	−0.15	−0.38	0.60
1.07	−0.09	−0.20	−0.18	−0.39	−0.42	0.48
1.08	−0.09	−0.23	−0.15	−0.38	−0.34	0.47
1.09	−0.08	−0.27	−0.13	−0.35	−0.29	0.24
1.1	−0.08	−0.29	−0.13	−0.48	−0.24	0.12
All	−0.22	0.37	−0.39	0.35	−0.61	1.40

options, although it is impossible to express theses increases as percentages, since they are mostly from negative to positive values. It is especially noteworthy that all payoffs for the 21-30 days category are negative before COVID and all are positive after COVID indicating that it was, on average profitable to buy these options in all strike price categories ranging from ITM to OTM. Nevertheless, the largest increases are for ITM options. In fact, during COVID, on average, ITM options are profitable for all

Figure 6: Percentage change in premiums

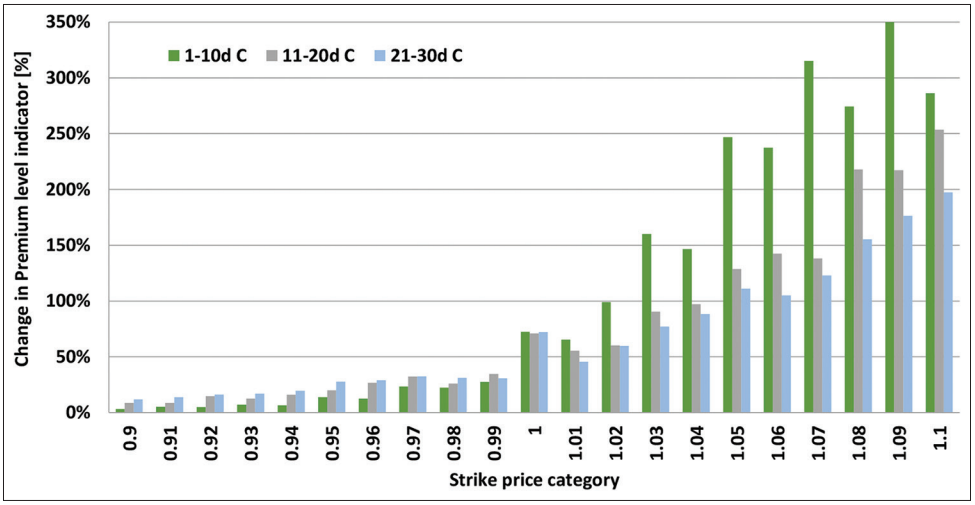


Figure 7: *Realized* indicator values

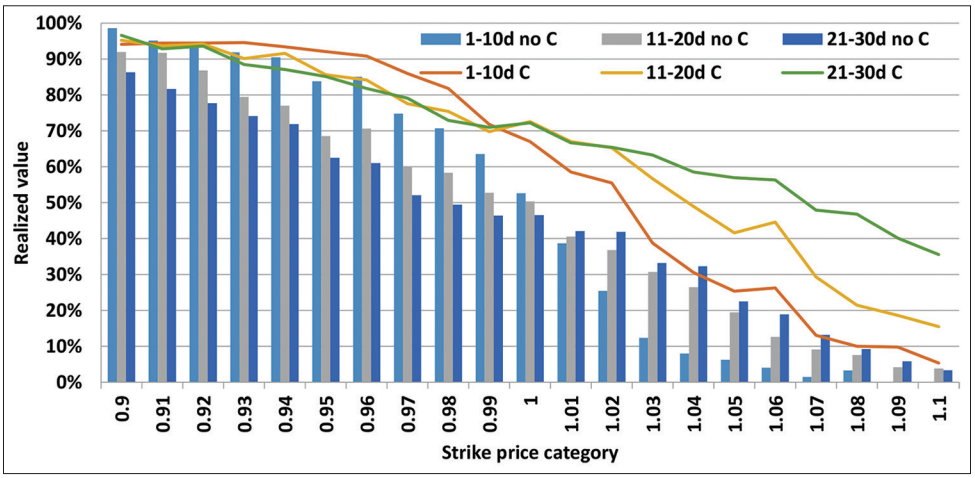
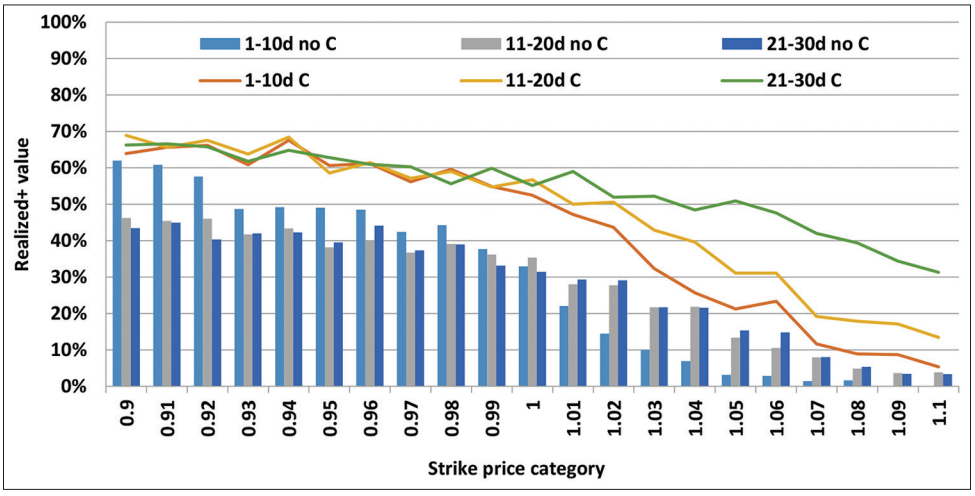


Figure 8: *Realized*$_+$ indicator values



strike price categories and all times to expiry, while on average they were unprofitable for all these categories before COVID.

Payoff standard deviations have increased significantly during COVID. On average, by a factor of 2.25, 1.64 and 1.99 during COVID for the 1-10 days, 21-20 days and 21-30 days categories respectively (Figure 10). As expected, the greatest increases in volatility are for the shortest term (1-10 days) OTM options since these are in general most unlikely to result in a profit, but may be profitable during especially turbulent conditions, such as during COVID.

Figure 9: Average payoff values (USD/b)

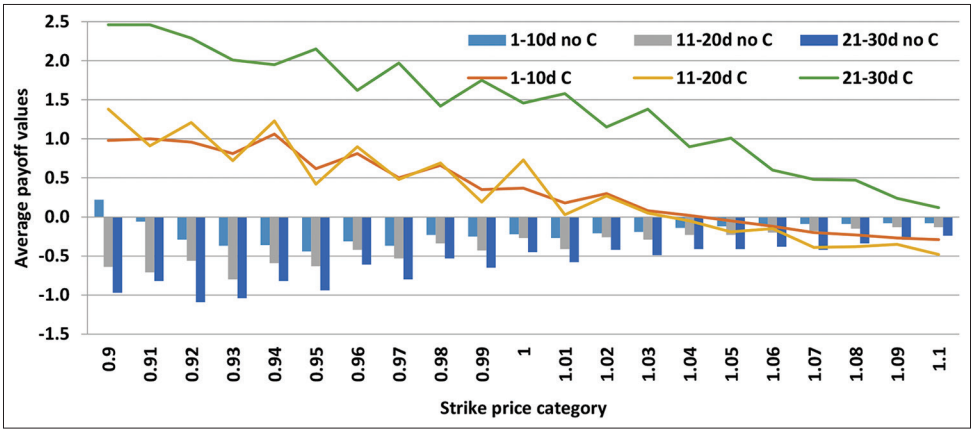


Figure 10: Standard deviation of payoff (USD/b)

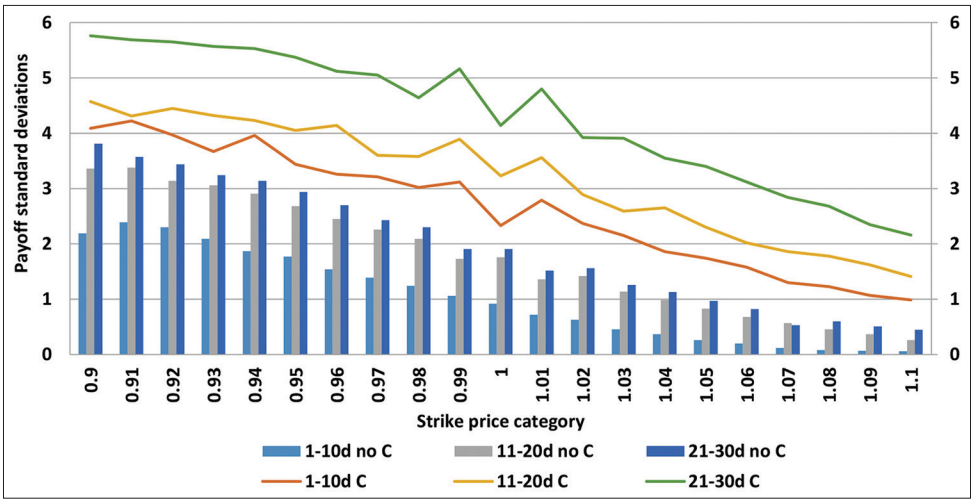
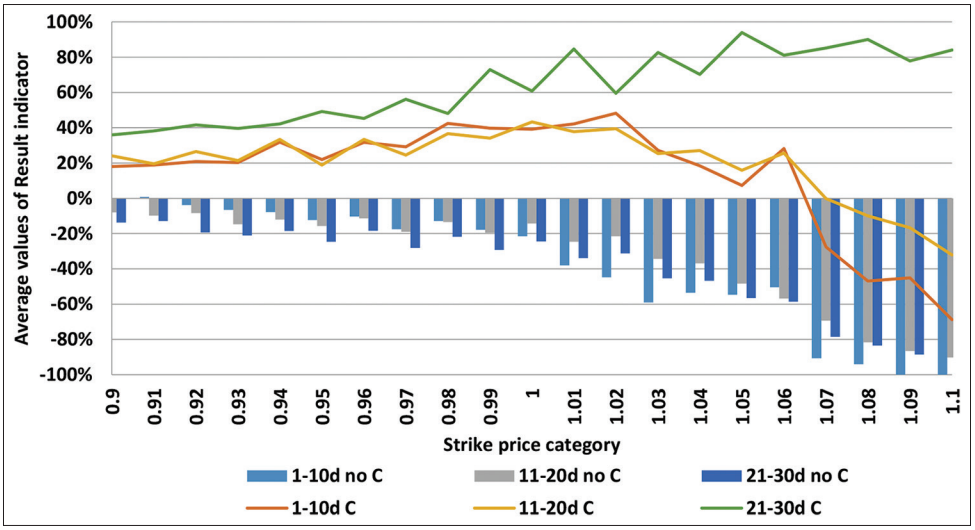


Figure 11: Average values of the *result* indicator



The last part of the call option market analysis deals with the value of the Result indicator (Formula [4]). Its value should be interpreted as the rate of return on the capital invested by the buyer of an option (i.e. option premium). It has a value in the range of -100% to +infinity. A value of -100% means that the buyer of the option did not exercise it and suffered a loss equal to the option premium. If the value is negative but greater than -100%, the option was exercised, but the increase in the price of WTI oil was lower than the option premium paid by the option buyer. Positive values of the indicator were achieved in the case of exercising the option with a profit. The analysis of the Result indicator complements the analyzes of the Realized and Realized+ indicators, as well

Table 9: Average values of *result* indicator

Strike price category (K)	Time category (t)					
	1-10 days		11-20 days		21-30 days	
	COVID category		COVID category		COVID category	
Strike price category (K)	0 (%)	1 (%)	0 (%)	1 (%)	0 (%)	1 (%)
0.9	4.98	17.98	−7.93	24.06	−13.78	36.01
0.91	0.79	18.91	−9.85	19.59	−12.82	38.20
0.92	−3.78	20.79	−8.33	26.50	−19.44	41.68
0.93	−6.51	20.35	−14.78	21.43	−21.10	39.58
0.94	−7.82	31.84	−12.09	33.45	−18.58	42.12
0.95	−12.31	21.98	−15.77	18.86	−24.58	49.29
0.96	−10.28	31.72	−11.28	33.46	−18.46	45.34
0.97	−17.52	29.15	−18.89	24.56	−28.18	56.22
0.98	−12.86	42.41	−13.43	36.70	−21.77	48.15
0.99	−17.79	39.80	−19.47	34.06	−29.32	72.89
1	−21.45	39.22	−14.26	43.33	−24.51	60.83
1.01	−38.00	42.13	−24.59	37.83	−33.99	84.66
1.02	−44.80	48.21	−21.44	39.55	−31.28	59.60
1.03	−59.02	27.20	−34.40	25.40	−45.35	82.71
1.04	−53.57	18.45	−36.86	27.05	−46.74	70.27
1.05	−54.64	7.30	−48.31	15.96	−56.53	94.06
1.06	−50.41	28.13	−56.84	25.70	−58.66	81.18
1.07	−90.71	−27.62	−69.36	−0.15	−78.48	85.27
1.08	−94.05	−46.90	−81.63	−9.92	−83.41	90.03
1.09	−100.00	−45.10	−86.65	−16.67	−88.50	77.84
1.1	−100.00	−68.76	−90.23	−32.14	−90.86	84.16
All	−34.99	14.95	−33.53	19.52	−40.84	63.15

as the value of option premiums and the payout function. The values of the Result indicator are presented in Table 9 and shown in Figure 11.

The *Result* indicator was negative for almost all option categories before the COVID-19 outbreak, and its value decreased as the strike price increased. This is consistent with the average payout values analyzed earlier. After the outbreak of the pandemic, the situation was completely different-in 54 out of 63 options categories, the *Result* indicator was positive. For options with an exercise time of up to 20 days, the most profitable strategy was the purchase of options with an exercise price differing from the oil price on the day of opening the position by no more than 2% (K_0 Category 0.98-1.02). For these options, the rate of return was 34-48%. Even better results, based on the value of the *Result* indicator, could be achieved for options with a maturity of 21-30 days. In this time category, it was profitable to buy call options from each strike price category. The average value of the *Result* indicator was over 63% and it was the highest for options from categories 1.05 (94%) and 1.08 (90%). Thus, these options were deeply OTM, which means that they were relatively cheap options (up to half the price of ATM options).

6. CONCLUSIONS

The aim of this article was to investigate the market for options on WTI crude oil, which is processed primarily in the USA. The commodity market has always been very volatile, which prompts both speculators and investors to use commodity derivatives. Options, as a special group of these instruments, provide an opportunity to hedge against negative consequences of price fluctuations. The authors analyzed selected parameters of US call options on WTI crude oil and showed what levels of profits and losses may be expected by entities holding long positions in such options in the period before and after the outbreak of the COVID-19 pandemic.

A preliminary analysis of the data showed that during the pandemic, the volatility of prices on the oil market was much higher than before, which corresponds to a significant increase in the value of implied volatility (on average by 30% for options from the 1-10d category and 50% for options from the 11-20d and 21-30d categories, with the largest increase of 70% for ATM options). The high level of implied volatility resulted in higher option premiums. Their average values after the outbreak of the pandemic increased by approx. 50%, and this increase was the highest for options with the shortest time to maturity. The largest increases in the value of option premiums were for options with the highest exercise prices (up to a 4-fold increase compared to the period before the pandemic). The time of the pandemic was also favorable to the exercise of the options themselves-in over 64% of cases, the price of WTI oil turned out to be higher than the exercise price set by the buyer of the option, and for nearly 50% of the buyers of call options, it was realized with a profit. These values are much higher than before the outbreak of the pandemic. From March 1, 2018 to March 1, 2020, *Realized* and *Realized+* ratios for all call options amounted to 46% and 28%, respectively. Despite much higher option premiums, the frequent exercise of call options after March 1, 2020 with a profit resulted in much higher average payout values and rates of return. In over 85% of the option categories, they had positive values and were the highest for options with the longest execution time (Category 21-30d). Research has shown particularly high rates of return for OTM options, while the highest payout values were achieved for ITM options. Analyzes show that hedging against oil price increases with the use of call options may be effective during unpredictable events such as the COVID-19 pandemic and likely the war in Ukraine-that aspect will be explored in a future article. The authors of the article will continue research on the commodity options market, expanding their analyzes to include the most recent months, during which the geopolitical situation was certainly not favorable to stabilizing the commodities market.

7. ACKNOWLEDGEMENT

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