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ARMED CONFLICTS AND PRICE VOLATILITY OF CRUDE OIL: INSIGHTS FROM HISTORICAL DATA

Armed conflicts and other geopolitical events are known to significantly influence the dynamics of the global crude oil market. In this study, we explore how military warfare, specifically major armed conflicts from 1989 to 2022, impacts fluctuations in crude oil prices. Our analysis identifies 16 distinct volatility spikes, with approximately half occurring within a 28-day window surrounding the onset of armed conflicts. These findings prove the substantial impact that geopolitical tensions, particularly interstate conflicts, have on global oil prices. Through an examination of oil price behavior before and after conflict initiation, we assess volatility trends in the 30 days preceding and 180 days following the outbreaks. The results demonstrate that interstate conflicts, especially those involving major geopolitical players, amplify price volatility more significantly than intrastate conflicts. The study also reveals that the magnitude of volatility changes depends not only on the conflict's scale but also on the region's significance to global oil supply chains. Notably, large-scale geopolitical events such as Russia's full-scale invasion of Ukraine and the Gulf War were associated with some of the most notable spikes in oil price volatility. Additionally, we examine the timing of these volatility spikes, finding that markets typically react within an average of 26 days to major conflicts, although some events are anticipated by the market, resulting in pre-conflict volatility increases. Overall, our study provides valuable insights into the relationship between armed conflicts and oil price volatility, contributing to risk assessment, hedging strategies, and predictive modeling in the context of global commodity markets. This research also highlights the need for further exploration of how markets adapt to prolonged conflicts and geopolitical tensions.

Keywords: *economic uncertainty, market disruption, commodity markets, crude oil, global oil market, price volatility, armed conflict, military warfare, war.*

Introduction. The global oil market has been one of the major segments of the global commodity market. Along with a number of economic, financial, and social factors that shape the conditions for its functioning, the security situation and geopolitical tensions play an integral role. Recent years have seen a significant escalation of military and political confrontations, stagnation of the global security situation, and deepening geo-economic fragmentation. In this context, it is essential to comprehensively study the effects that the escalation of armed

confrontations provokes upon price fluctuations in global commodity markets, especially the oil market.

For instance, Russia's full-scale invasion of Ukraine triggered one of the most severe oil shocks in recent decades, which led to deepening market imbalances, extreme price fluctuations, and increased levels of uncertainty. The analysis of historical data allows us to derive conclusions about the extent to which wars affect the magnitude of price fluctuations, as well as to trace patterns of signals of volatility spikes in the early stages. The results of such an examination will provide a deeper perspective on the impact of geopolitical factors on global markets and will be helpful in identifying major volatility fluctuations in the future, improving forecasting models, and better understanding of fundamental market mechanisms.

Review of related research and publications. Military conflicts and wars have a significant impact on oil price volatility. Numerous studies have shown that wars, armed conflicts, and other geopolitical tensions contribute to the volatility of crude oil prices. In particular, D. S. Painter [35] investigates the role of oil in the geopolitics during the Cold War and the oil crises of the 1970s when the interdependence between the oil market and geopolitical turbulence was gaining momentum. A comprehensive overview of the impacts of wars on oil prices was suggested by Y. Sun [42], in which the author provides the rationale for oil price fluctuations in times of wars and discusses the peculiarities of the oil price changes during different wars, namely those in Iraq and Ukraine.

Indeed, one of the most prominent examples of how global violence affects markets is the Russo-Ukrainian war that has significantly impacted the global economy. N. Skrypnyk and B. Zavalii [41] discuss the implications of the warfare, such as surging inflation, disruptions of supply chains, deepening trade imbalances, as well as investigate the impact of sanctions on the aggressor state and related parties. T. Li et al. [30] discuss the main reasons for oil price volatility, suggesting that major geopolitical events, such as the Russo-Ukrainian war, can lead to significant disruptions or uncertainties in future supply and demand, causing oil prices to fluctuate. Of particular interest is the study by Q. Zhang et al. [44], as the authors examine specific channels through which geopolitical conflicts, such as the Russia's full-scale invasion of Ukraine, exert their influence, impacting speculation, inventory, and demand-supply balances. I. Appiah-Otoo [5] analyzes the impact that the ongoing Russo-Ukrainian war has on the domestic oil prices in the US.

Not only the full-scale Russian invasion of Ukraine has been of particular interest of scholars. Numerous armed conflicts of the past have been studied in their relation to the dynamics of global commodity markets. For instance, R. E. Looney [31] provides a thorough overview of the market interpretations of military developments during the War in Iraq. M. A. El-Gamal and A. M. Jaffe [17], on the other hand, analyze the cyclical interrelation between violence outbreaks in the Middle East and oil supply disruptions, leading to price fluctuations. A. J. G. Gordon and L. A. H. Recio [22] suggest an event-study model to assess short-term impacts of the War in Ukraine as of 2018.

Major global events, such as the Covid-19 pandemic and Russo-Ukrainian war, serve as a threshold for improving predictive models of commodity prices. For instance, Y. Cai et. al. [13] incorporate most recent pricing and volatility data to improve the performance of predictive models driven by artificial neural network algorithms.

Not only wars and armed conflicts, but also global terrorism has been defined as one the major factors impacting the global oil market dynamics. For instance, C. Kollias et al. [28] investigate the covariance between oil prices and the indices of major stock markets. J. R. V. Orbaneja et al. [33] suggest a study on the influence of terrorist attacks on the oil market based on the location of such attacks, their type, and severity.

Apart from military warfare, studies have examined the impact of geopolitical tensions in the trade and pricing domain, often referred to as oil price wars. For instance, M. H. Khan et. al. [27] investigate the effects between crude oil price volatility and stock returns during major oil price wars between 1991 and 2020.

Besides, some studies argue that oil, and namely its scarcity, can be one of the factors that increase the likelihood of wars. For instance, P. Le Billon and A. Cervantes [29] suggest a concept of scarcity-driven wars, using oil as a prominent example for their analysis.

Overall, our paper advances these studies by exploring new perspectives on the relationship between military conflicts and crude oil price volatility.

Methods of the research. In this study, we use general scientific and special methods of research of economic and financial processes. The methods used to accomplish the objectives of the study are as follows: historical – to assess past pricing and volatility trends, as well as to examine warfare events from 1989 to 2022; induction and deduction – to study individual components and factors of price fluctuations and to determine temporal linkages between the studied phenomena; analysis and synthesis – to identify the relationship between military conflicts and crude oil price volatility, identifying volatility patters, differentiating influences, and developing new perspectives; descriptive analysis and observation – to build and explain tables, graphs, and charts; quantitative algorithmization methods – to perform mathematical calculations and computations, including data manipulation, grouping, and trend assessments. Namely, we employ logarithmic return and rolling volatility calculations to assess annualized volatility, data grouping based on quantile functions and temporal proximity criteria to identify volatility jumps and war-related spike periods, and locally estimated scatterplot smoothing to draw price trends ignoring daily fluctuations.

Main research material. According to the research of the *Our World in Data* (*OWID*) project (see [23]), increased cooperation and normalization of political relations between countries in the 1990s and 2000s, mainly within the European Union, contributed to the rapid formation of secure communities and reduced tensions in international relations. However, in recent years, there has been significant escalation of military and political confrontations both globally and locally. For instance, the share of pairwise relations between countries that can be attributed to secure communities peaked in 2013 at 18.73%. However, in 2020, this figure dropped to 17.03%. On the other hand, the share of relations belonging to the group of severe rivalry increased from 1.44% to 2.53% during the same period [ibid.]. Such dynamics indicate stagnation of the international security situation, aggravation of military and political crises, and increased tensions between states.

This research focuses on wars that have been empirically identified as the major armed conflicts from 1989 to 2022 (see Table 1). These conflicts are commonly acknowledged as significant both within academic circles and in public discourse. The aim is to highlight the most impactful events, thus excluding less significant conflicts which do not contribute substantially to the scope of this study.

Table 1

Major armed conflicts from 1989 to 2022

Conflict	Start Date	Reference
Gulf War	02 August 1990	[11]
Somali Civil War	26 January 1991	[8]
Croatian War of Independence	31 March 1991	[24]
Sierra Leone Civil War	23 March 1991	[32]
Yugoslav Wars	25 June 1991	[25]
Bosnian War	06 April 1992	[18]
Tajikistani Civil War	05 May 1992	[40]
First Chechen War	11 December 1994	[43]
Kosovo War	28 February 1998	[19]
Eritrean–Ethiopian War	06 May 1998	[6]
Second Congo War	02 August 1998	[38]
Second Intifada	28 September 2000	[36]
War in Afghanistan	07 October 2001	[21]
War in Darfur	26 February 2003	[1]
Iraq War	20 March 2003	[9]
Mexican Drug War	11 December 2006	[14]
Russian invasion of Georgia	07 August 2008	[34]
Arab Spring Conflicts	17 December 2010	[4]
Libyan Civil War	15 February 2011	[10]
Syrian Civil War	15 March 2011	[2]
South Sudanese Civil War	15 December 2013	[20]
Annexation of Crimea	27 February 2014	[15]
Russo-Ukrainian War in Donbass	12 April 2014	[26]
Second Libyan Civil War	16 May 2014	[39]
Yemeni Civil War	19 September 2014	[7]
Nagorno-Karabakh Conflict	27 September 2020	[3]
Tigray War	04 November 2020	[12]
Full-scale Russian invasion of Ukraine	24 February 2022	[37]

Source: see references in the table above

As a benchmark for global oil prices, we utilize historical daily spot prices of WTI crude oil at Cushing, OK [16]. Based on these data, we calculate annualized volatility in order to trace the dynamics of price fluctuations, using the common approach. In particular, the daily log return R_t for day t is given by:

$$R_t = \log\left(\frac{P_t}{P_{t-1}}\right) \tag{1}$$

where P_t is the price on day t and P_{t-1} is the price on the previous day $t-1$.

Next, we calculate rolling 30-day volatility:

$$\sigma_{30,t} = \sqrt{\frac{1}{29}\sum_{i=t-29}^{t}\left(R_i - \bar{R}_{30,t}\right)^2} \tag{2}$$

where $\sigma_{30,t}$ is the rolling 30-day volatility; $\bar{R}_{30,t}$ is the average log return over the 30-day window:

$$\bar{R}_{30,t} = \frac{1}{30} \sum_{i=t-29}^{t} R_i \quad (3)$$

To ensure accurate calculation of 30-day rolling volatility for the studied period, we incorporated extra 30 input points from 18 November 1988 to 30 December 1988 to account for the dates prior to the start of year 1989. To annualize the 30-day rolling volatility, we multiply it by the square root of the number of trading days in a year (typically 252 days):

$$\sigma_{annual,t} = \sigma_{30,t} \times \sqrt{252} \quad (4)$$

where $\sigma_{annual,t}$ is annualized volatility; $\sigma_{30,t}$ is the rolling 30-day volatility.

Obtained results for annualized volatility are described in Table 2. For improved visual comprehension, we plot obtained volatility values against military conflict start days (see Figure 1).

Table 2

Descriptive Statistics of Annualized Volatility

Statistic	Count	Mean	Std	Min	25%	50%	75%	Max
Value	8530	0.35968	0.19224	0.11177	0.25019	0.31573	0.41641	2.33433

Source: calculated by the author

Note: Count is the number of data points; Mean is the arithmetic average; Std is the standard deviation; Min is the minimal value; 25% is the first quartile; 50% is the median or second quartile; 75% is the third quartile; and Max is the maximal value.

Next, we identify significant volatility jumps. Let $V = \{v_i\}, i = \overline{1,n}$ denote the dataset of annualized volatilities. The 95th percentile threshold G is determined using the empirical quantile function $Q(p)$, where $p = 0.95$ so that $G = Q(0.95)$, denoting the value below which 95% of the data points in V lie. As soon as we determine G, we identify the indices i such that the volatility v_i exceeds G:

$$J = \{i \mid v_i > G\} \quad (5)$$

where J is the set of indices i for which the annualized volatility v_i is greater than G.

We assume that neighboring jump points are part of the same continuous volatility spike. After a series of mathematical transformations, we obtain the set of volatility spike periods (see Figure 2):

$$I = \{(S_i, E_i, SV_i) \mid i = 1, \dots, len(S)\} \quad (6)$$

where I is the set of volatility spikes characterized by start dates S_i, end dates E_i, and severities SV_i, the latter representing the maximum volatility during the spike period, with $len(S)$ being the total number of volatility spikes.

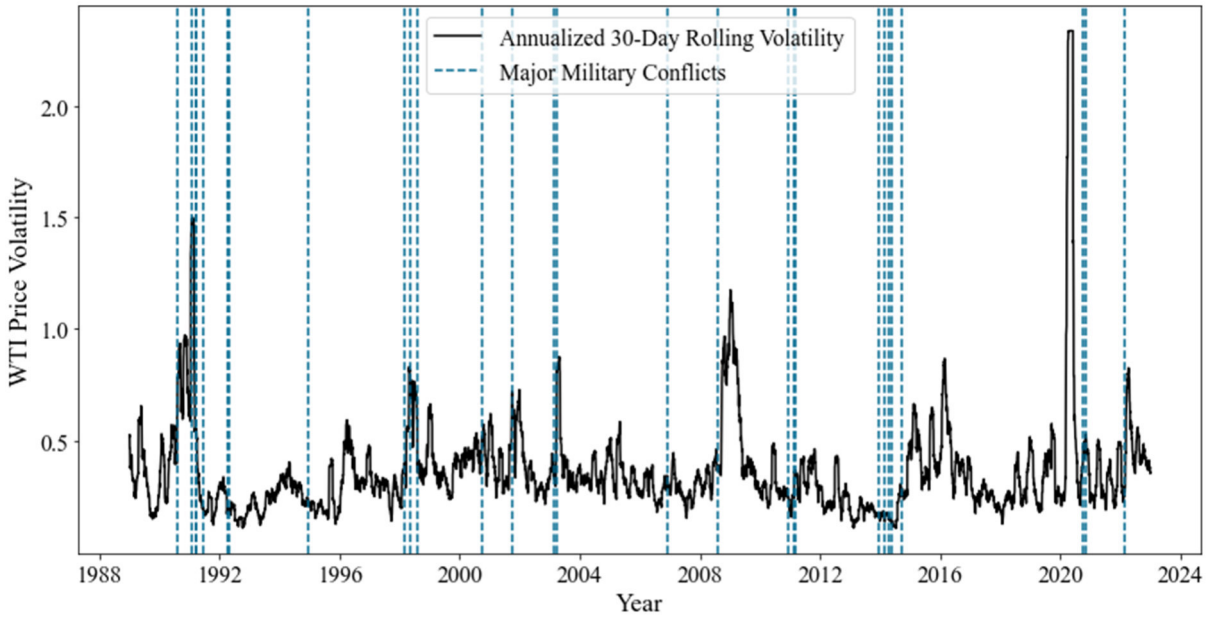


Figure 1. Crude Oil Price Volatility and Major Military Conflicts (1989 – 2022)
Source: developed by the author

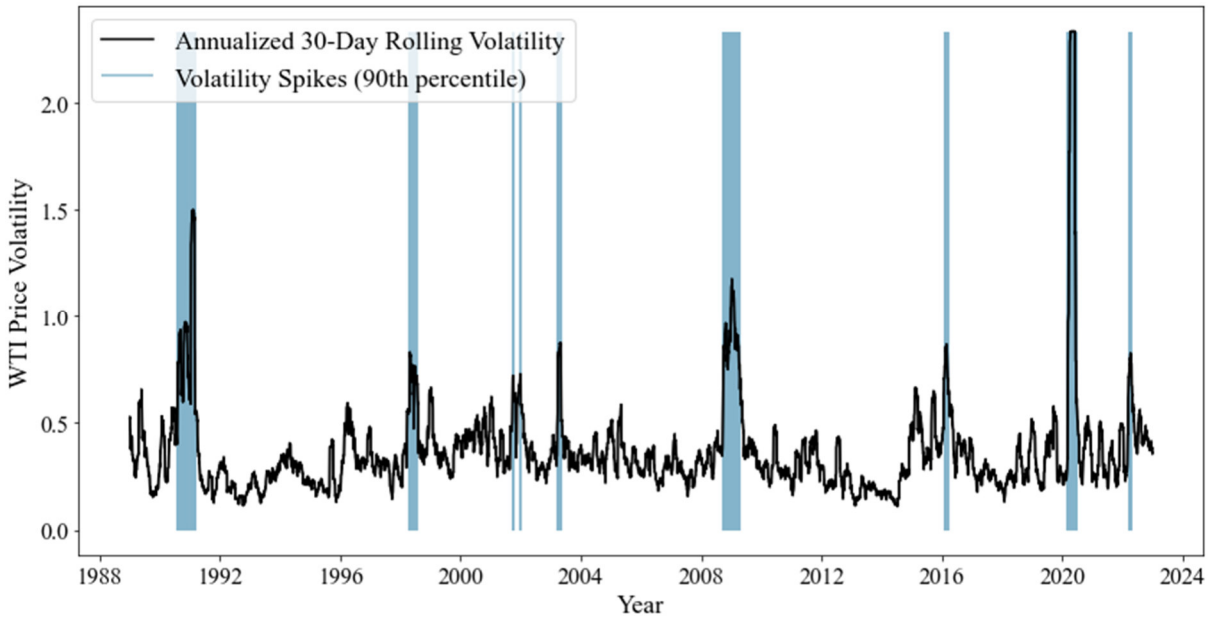


Figure 2. Crude Oil Price Volatility and Major Volatility Spikes (1989 – 2022)
Source: developed by the author

Overall, the set contains 16 spike periods and respective severity values. Having obtained these figures, we investigate whether a spike in volatility can be attributed to a specific armed conflict. By denoting the start day of the *i*-th war as W_i and start date of the *k*-th spike as S_k, we define the window of +/– 28 days around each war start date as $[W_i - 14, W_i + 14]$. Hence, the condition ensuring that *k* is a war-related spike is as follows (see Figure 3):

$$K = \{S_k \mid |S_k - W_i| \leq 14\} \quad (7)$$

where *K* is the set of war-related spikes; S_k is the start date of the *k*-th spike; W_i is the start date of the *i*-th war.

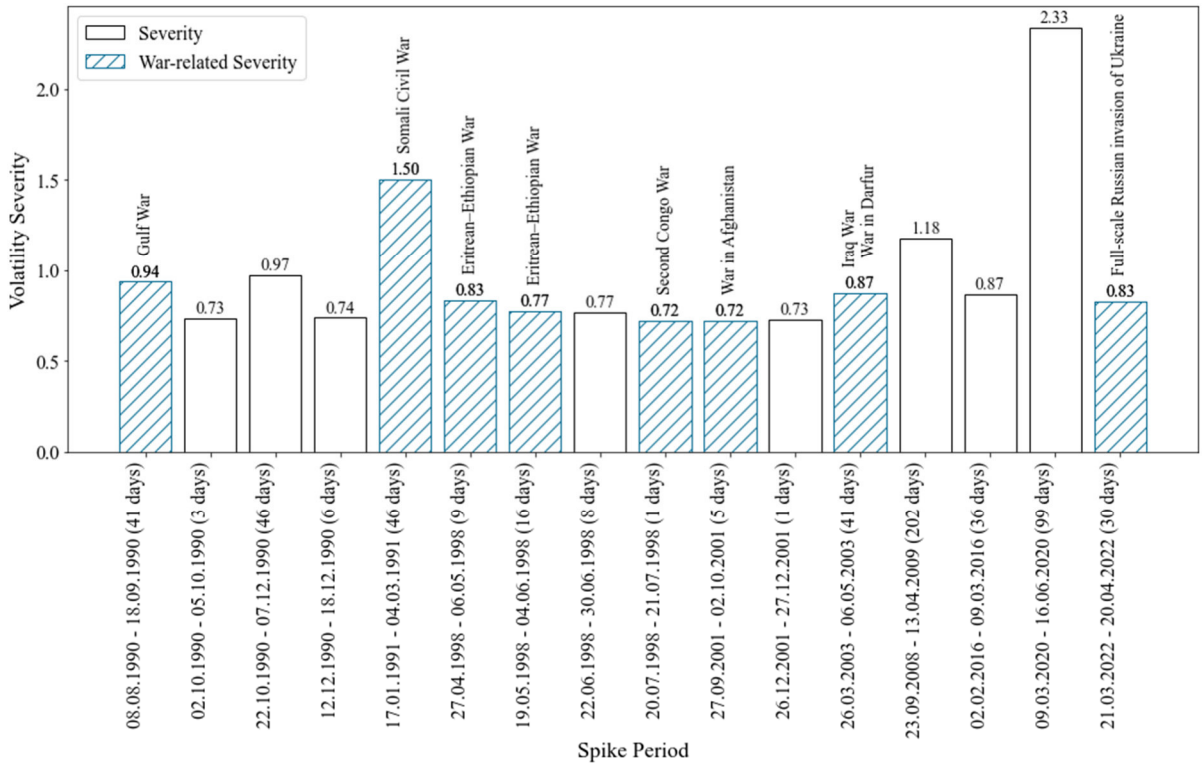


Figure 3. Volatility Spikes and Their Severities (1989 – 2022)

Source: developed by the author

As the next step, we analyze average volatility 30 days before and 180 after the outbreak date of each conflict, obtaining values for changes in average volatilities around each military conflict. Interestingly, the highest volatility increases were observed for such conflicts as Russian invasion of Georgia (+0.389), Gulf War (+0.375), full-scale Russian invasion of Ukraine (+0.283), Kosovo War (+0.217), Yemeni Civil War (+0.151), Iraq War (+0.123), Libyan Civil War (+0.105), and War in Darfur (+0.104). Other conflicts exhibited either mild increase in volatility, i.e., up to 0.05, or decrease, implying modest to no impact on volatility. Decreases in volatility were observed mostly in relation to interstate armed conflicts of local scale and intrastate civil wars, whilst increase of average volatility, either significant or modest, was related primarily to interstate conflicts where major geopolitical players were engaged or those that took place in oil-producing regions such as the Middle East.

In the last part of our study, we analyze how the global oil market prices respond to military conflicts. By looking at how long it takes for volatility to spike after a conflict starts, we aim to gauge the market's sensitivity and reaction time to such events. For such a purpose, we define the pre-conflict period as the 90 days leading up to the conflict start date, and the post-conflict period as the 360 days following the conflict outbreak, which can be together defined as $T = [W_i - 90, W_i + 360]$, following the notation suggested previously. To smooth the volatility data, we apply locally estimated scatterplot smoothing (LOESS) helping to draw the overall trend $R(t)$ ignoring daily fluctuations, such that $R(t) = LOESS(V(t))$ for $t \in T$. Due to shorter periods under study, we define significant trend increases to be those in the top 1% of all changes, namely $\Delta R(t) = R(t+1) - R(t)$ for $t \in T$ and $Q(p)$ where $p = 0.99$ so that $g = Q(0.99)$. Hence, the condition of such a volatility trend increase to be significant is as follows:

$$L = \{t \in T \mid \Delta R(t) > g\} \quad (8)$$

where L is the set containing the time points t where the increase in volatility $\Delta R(t)$ is greater than g.

If a significant increase in volatility is found, we calculate how many days it took for this increase to happen before or after the conflict started. Let l be the first increase observed. Then,

$$t_l = \begin{cases} \min\{t \in L\} & \text{if } L \neq \emptyset \\ \infty & \text{if } L = \emptyset \end{cases} \quad (9)$$

where t_l is the time point related to the first increase.

Hence, if t_l is defined, we calculate the delay d as the difference between the date of first increase l and the war start date W_i:

$$d = \begin{cases} l - W_i & \text{if } l \neq \infty \\ \infty & \text{if } l = \infty \end{cases} \quad (10)$$

For wars that can be related to volatility spikes, the mean delay of approximately 26 days suggests that the market tends to react relatively quickly to such conflicts (see Table 3). This means that within about a month of the conflict's onset, volatility tends to either increase significantly or the expectation of increased volatility starts manifesting.

Table 3

Descriptive Statistics of Volatility Increase Delays

Group	Count	Mean	Std	Min	25%	50%	75%	Max
Wars related to volatility spikes	8	25.875	77.207397	-53	-22.5	5	47.75	159
Wars unrelated to volatility spikes	20	126.2	133.201312	-72	31	101.5	251.5	3337

Source: calculated by the author

For the other group of wars, the mean delay of about 126 days indicates a much longer period. This suggests that for conflicts where volatility did not increase significantly, markets typically did not respond immediately or in the short term. Longer delays may indicate that other factors or developments were more influential in driving market conditions, i.e., the market was influenced by factors other than the conflict itself. These could include economic developments, financial uncertainties, or other global events that overshadowed the direct impact of such a conflict.

Instances where volatility increases occurred before the conflict started, i.e., negative delays, suggest that the market might have anticipated the conflict or reacted to early signs or tensions leading up to it. This anticipation can be a precursor to a larger volatility spike once the conflict vividly commences. If volatility does not show a significant rise within approximately a month (26 days) after the start of the conflict, it is less likely to lead to sustained or notable market volatility. This threshold can be used as a heuristic to gauge the initial impact of conflicts on the global oil market.

Conclusions and prospects for further research. Our study offers a data-driven analysis of the impact of military conflicts on global oil price volatility. Specifically, we investigate

the connection between armed conflicts and the volatility of spot WTI crude oil prices from 1989 to 2022.

Our research proves that armed conflicts tend to lead to significant spikes in crude oil volatility. In particular, the analysis identified 16 distinct volatility spike periods, with such spikes being likely to cluster around the onset of large-scale armed conflicts. Furthermore, we found that interstate conflicts, especially those involving major global players or occurring in regions critical to oil supply, are more likely to cause substantial increases in oil price volatility. In contrast, intrastate conflicts or those of a localized nature often result in minimal changes or even decreases in volatility, suggesting a more complex relationship between conflict scale and market response.

Moreover, our analysis revealed that markets generally react rapidly to conflicts that lead to significant volatility increases, with an average delay of approximately 26 days for related wars. Conversely, conflicts not associated with volatility increases saw a much longer average delay of 126 days. This disparity highlights the market's sensitivity to certain geopolitical events while indicating that other factors may influence volatility in the absence of immediate conflict-driven impacts. The identification of significant volatility increases before the actual outbreak of conflicts indicates that the global oil market can anticipate impending geopolitical tensions. This preemptive behavior suggests that market participants react not only to actual events but also to perceived risks and early indicators of potential conflicts.

We believe that future research could extend the analysis by examining how conflicts in specific regions impact the crude oil market. Also, it would be worth investigating how the market adapts over time to recurring conflicts or prolonging geopolitical tensions by tracking how market sensitivity evolves and whether volatility impacts diminish over time. Finally, further studies could incorporate other economic variables, such as currency rate fluctuations, interest rate dynamics, and fluctuation of stock and commodity indices, as well as integrate machine learning and predictive analysis techniques.

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ЗБРОЙНІ КОНФЛІКТИ ТА ВОЛАТИЛЬНІСТЬ ЦІН НА НАФТУ: АНАЛІЗ ІСТОРИЧНИХ ДАНИХ

Відомо, що збройні конфлікти та інші геополітичні чинники суттєво впливають на динаміку світового ринку нафти. У цьому дослідженні ми з'ясовуємо, як розгортання військових протистоянь, зокрема значних збройних конфліктів з 1989 по 2022 рік, впливає на коливання цін на нафту. Зокрема, ми розглядаємо найбільші військові конфлікти та їхній зв'язок зі стрибками волатильності поточних цін на нафту у період з 1989 по 2022 рік. У ході дослідження було виявлено 16 виразних сплесків волатильності протягом досліджуваного періоду, половина з яких припадає на 28-денний проміжок від дати початку конфлікту. Такі результати доводять, що геополітична напруженість – насамперед у формі міждержавних конфліктів – суттєво впливає на світові ціни на нафту. В роботі також досліджено середні показники волатильності до та після початку кожного з конфліктів, а також здійснено оцінку динаміки волатильності за 30 днів до та за 180 днів після початку таких конфліктів. Отримані результати свідчать, що війни між державами, особливо ті, у яких беруть участь великі геополітичні гравці, є більш значущими чинниками посилення волатильності світових цін на нафту, аніж внутрішні конфлікти. Результати дослідження також доводять, що величина зміни волатильності залежить не лише від масштабу кофлікту або його учасників, але й від важливості регіону розгортання протистояння для глобальних ланцюгів постачання нафти. Зокрема, такі значні геополітичні події, як повномасштабне вторгнення Росії в Україну та війна в Перській Затоці, були пов'язані з одними з найпомітніших сплесків волатильності цін на нафту. Крім того, ми дослідили часовий вимір таких сплесків і виявили, що ринки зазвичай реагують на великі конфлікти в середньому протягом 26 днів після їх початку. Втім розгортання геополітичної та воєнної напруженості нерідко передбачається ринком, що призводить до передчасного зростання волатильності. Загалом, наше дослідження містить вагомі напрацювання щодо зв'язку між волатильністю цін на нафту та розгортанням збройних конфліктів, які можуть бути застосовані при оцінці ринкових ризиків, розробці стратегій хеджування та прогностичному моделюванні в контексті світових товарних ринків. Дослідження також засвідчує необхідність подальшого вивчення того, як ринки адаптуються до тривалих конфліктів і геополітичної напруженості.

Ключові слова: *економічна невизначеність, ринкова нестабільність, товарні ринки, нафта, світовий ринок нафти, волатильність цін, збройний конфлікт, військове протистояння, війна.*