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Estimating the impact of the outbreak of wars on financial assets: Evidence from Russia-Ukraine conflict ☆

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ABSTRACT

This study analyzes the performance of the Shanghai Composite Index, S&P 500 index, WTI oil price, and LBMA gold price when wars took place, especially the Russia-Ukraine conflict. We employ empirical methods to explore the stability, instantaneous shock, and short-term shock regarding the abovementioned financial assets. We first adopt the event study method to ascertain whether the cumulative abnormal returns of the selected assets are significant when wars break out. Then, we use the permutation test to examine the significance of price level changes. Results show that only the Shanghai Composite Index is relatively stable. Second, the difference-in-differences model indicates that the 3 unstable assets all suffered positive shocks in their price levels within several days after the Russia-Ukraine conflict broke out. The parallel trend test confirms the validity of establishing the difference-in-differences model. Third, regression discontinuity is designed to measure the impact in a longer event window, suggesting the robustness of conclusions of the difference-in-differences model and revealing an upward trend before the conflict and a downward trend after the conflict of the financial assets. The study suggests that investors consider adjustments to investment strategies and governments take precautions to diminish the risk of the outbreak of wars.

1. Introduction

Warfare leaves terrible legacies [1]. As an extreme geopolitical event, the outbreak of war has nonnegligible impacts on the economic and financial system, including the tourism industry [2,3]. It could not only damage the infrastructure and economic base of belligerent regions but also trigger a shock to the global financial market through the channel of economic globalization. For instance, during the Persian Gulf War in the early 1990s, many telecommunication centers, bridges, roads, and other infrastructures in Iraq were destroyed, and the war caused WTI oil price to rise by \$15.92 [4]. High energy prices will increase the cost of production and

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consequently harm global economic development.

The outbreak of the Russia-Ukraine conflict is one of the recent black swan events. In 2019, the Verkhovna Rada (the Ukrainian legislature) passed an amendment to the Constitution of Ukraine, identifying obtaining EU and NATO membership as an irreversible strategic course.[2] Claiming to prevent the possible eastward expansion of NATO and maintain national security, Russia launched a "special military operation" and invaded Ukraine on February 24th, 2022, whose impact on the global economy was gradually revealed. Severe inflation occurred in the US, where the year-over-year Consumer Price Index was pushed up to 8.5 % in March2, 022.[3] In Europe, the progress of economic resurgence was also hindered. The International Monetary Fund cut the economic growth rate of the eurozone in 2022 by 0.8 % in April.[4] In the first quarter of 2022, China's year-over-year Producer Price Index was 8.7 %,[5] higher than 8.1 % in 2021. The data above demonstrates the extensive economic impact of the Russia-Ukraine conflict, attaching importance to detailed research and analysis.

Research on the impact of the Russia-Ukraine conflict has been carried out by scholars in various fields. In the financial field, Agyei [5] found that the stock markets of the top seven emerging countries (E7 countries) exhibited heterogeneous and asymmetric reactions. Furthermore, Bossman and Gubareva [6] concluded that except for China and Russia, other E7 stocks responded positively when the conflict broke out. Several studies have also confirmed a significant impact on other stock markets and the cryptocurrency market [7–10]. In the food science field, Ben and El Bilali [11] pointed out that the conflict threatened global food security due to the slump in Ukraine's export capacity, labor shortages, and insufficient access to fertilizers. Jagtap et al. [12] focused their research on food supply chains, arguing that links such as production, sourcing, manufacturing, processing, and logistics all suffered due to the conflict. In the environmental field, research by Rawtani et al. [13] indicated that the conflict gave rise to a range of environmental damages, including water pollution, soil contamination, deteriorating sanitary conditions, and possible nuclear leakage.

In this research, in addition to the Russia-Ukraine conflict, the Iraq War and the Libya War are also selected as the events for event study. Including multiple war or conflict events can help disclose general rules instead of being misdirected by specific phenomena. The selection criteria are as follows. First, all these wars took place in the 21st century, enabling them to reflect the impact of extreme events under the rapid dissemination of information. Financial markets can respond on the same trading day as a war occurs. Second, all the wars selected lasted for over 1 month. Their scale and duration brought considerable international attention and undeniable economic and financial influence. Third, these wars have definite dates of outbreak, which is essential for conducting empirical analysis. The Iraq War began on March 20, 2003, when the US, joined by the United Kingdom, Australia, and Poland, launched a "shock and awe" bombing campaign. The Libya war began on February 16th, 2011, when the demonstrators collided with security forces. The Russia-Ukraine conflict began on February 24, 2022, when Russia announced initiating a "special military operation".

Our study focuses on the impact of wars on major financial assets, especially the Russia-Ukraine conflict. The financial assets in this study contain the Shanghai Composite Index, S&P 500 index, WTI oil price, and London Bullion Market Association (LBMA) gold price. The Shanghai Composite Index and S&P 500 index can reflect the situation of the financial systems of China and the USA, which are the top 2 greatest economies in the world. Based on existing literature, oil price shocks have an extensive influence on the state economy and financial system and have attracted much research [14,15]. Many scholars regard gold as a safe haven in extreme stock market conditions [16,17]. However, whether the gold price can maintain a stable performance when facing the outbreak of wars remains an interesting proposition to be checked.

The research objective of this study is to evaluate the impact of an outbreak of the Russia-Ukraine conflict on selected financial assets. To fulfill this target, the event study method and the permutation test are first applied to data of selected financial assets during the Iraq war, the Libya war and the Russia-Ukraine conflict to evaluate which financial assets have stable performance. Then, based on the stability, the financial assets are divided into a treatment group and a control group, and for each unstable financial asset, a DID model is established to measure the impact of an outbreak of the Russia-Ukraine conflict.

Studies on the impact of wars are necessary for both investors and policy makers. First, wars have an evidenced impact on financial markets [18], which brings augmented risk to the investment market and will inevitably influence the profit of investors. Research is thus needed to figure out how different financial markets and assets react and whether there exists a regular pattern. Such research can guide financial investors. Second, this study finds that the oil price also changes significantly cause by wars. Since the oil reserve is an important strategic asset related to domestic production, research is needed to give suggestions to policymakers about the oil reserve when wars break out.

The main contributions of this paper lie in the following three aspects. First, we conduct a systematic event study by incorporating both multiple events and multiple assets, which enables us to figure out the regular pattern of multiple assets across history at one time. Second, this paper uses the event study method and the permutation test to establish the treatment group and the control group of the DID model. In the DID model, the control group consists of individuals unaffected by the event, while the treatment group is composed of individuals affected by the event. When applying the DID model to evaluate policy impact, regions implementing the policy can simply be divided into the treatment group. However, in the background of war, whether a specific financial asset is affected by the outbreak of war is not clear. This paper provides a solution that the event study method and the permutation test can be jointly adopted to distinguish between the treatment group and the control group. The third contribution lies in the conclusion. It is found that the

[2] https://www.rferl.org/a/ukraine-president-signs-constitutional-amendment-on-nato-eu-membership/29779430.html.

[3] https://fred.stlouisfed.org/series/CPIAUCSL.

[4] The regional economic outlook of IMF issued in April 2022 can be downloaded from the following website. https://www.imf.org/-/media/Files/Publications/REO/EUR/2022/April/English/text.ashx.

[5] http://www.stats.gov.cn/english/PressRelease/202204/t20220412_1829529.html.

Shanghai Composite Index has a relatively stable performance in comparison with the other selected financial assets, which indicates that the Shanghai Composite Index might serve as a safe haven for investors when wars break out.

The rest of this paper is organized as follows. Section 2 reviews the relevant studies on the impact of wars on financial assets. Section 3 introduces the methodology, interprets our model, and describes the data. The results are displayed in Section 4, and conclusions are reached in Section 5.

2. Literature review

We investigate the existing literature on the impact of extreme events on financial assets and find that much relevant literature adopts the method of event study. This class of literature can be further divided into two categories, namely, analyzing the reaction of one particular financial asset using a series of extreme historical events and analyzing the impact of one particular extreme event on a series of financial assets. In the event study part of our study, we incorporate both multiple financial assets and multiple extreme events, providing more insights into the topic. In the remaining part of this section, we introduce three groups of relevant literature, which are event studies focusing on one financial asset, event studies focusing on one extreme event, and relevant studies using other methods.

Several studies have researched the reaction of one particular financial asset to extreme events utilizing an event study approach. Hassan et al. [19] studied the impact of six Indian border disputes on the Indian stock index NIFTY. They found that heterogeneity occurred across different economic sectors. Loutia et al. [20] focused on the impact of OPEC announcements on oil prices. They found that OPEC production decisions, especially production cuts and maintenance, have a significant impact on WTI and Brent prices. Yang et al. [21] paid attention to gold future prices. They calculated the impact of six rounds of the Federal Reserve System's interest rate hikes from 1983 to 2018. Regarding stock markets, Piccoli et al. [22] found that Brazilian stocks tended to overreact after both positive and negative events, while Gu et al. [23] pointed out that the Chinese stock market reacted less significantly to Sino-US trade disputes than to non-trade disputes. The research targets of these event studies are all single. In our event study, we incorporate multiple financial assets, which enables us to make a comparison among them.

Some studies also focus on the financial impact of one selected extreme event utilizing event study. Van Geyt et al. [24] studied the influence of the 2007 global financial crisis on the Belgian stock market. Their results showed that abnormal returns during the financial crisis were significantly higher than those during normal periods. Tielmann and Schiereck [25] analyzed the consequences of Brexit. They concluded that UK-based logistic companies performed much poorer than those from Continental Europe, although both underwent negative shocks. He et al. [26] examined the reaction of Chinese industries to the COVID-19 pandemic. They found that transportation, mining, and environmental industries were adversely impacted while manufacturing, information technology and healthcare industries turned out to be resilient. Boubaker et al. [27] examined the impact of the Russia-Ukraine conflict on financial markets. They found negative cumulative abnormal returns among global stock market indices. In the subsequent work, Boubaker et al. [28] found a significant decline in returns of banks stock prices. Chortane and Pandey [29] found that a negative impact on the global currencies was brought about by the Russia-Ukraine conflict. The research above focuses on a single extreme event, making their conclusions lack generality. Our study covers a series of wars in the 21st century, which can provide a reference for possible conflicts ahead.

Some other methods are also proposed to measure the financial impact of extreme events. Using causal analysis, Koseoglu et al. [30] found a negative impact of the Russia-Ukraine conflict on the Moscow Exchange index, and Xu et al. [31] found a negative impact on the exchange rate of the Russian currency. Duan et al. [32] used the wavelet analysis technique and concluded that Venezuela's oil-dependent economy is severely affected by geopolitical instability. Zhang et al. [4] decomposed the time series of crude oil price into several intrinsic modes based on EMD. They found that the impact of extreme events can be measured from one or several

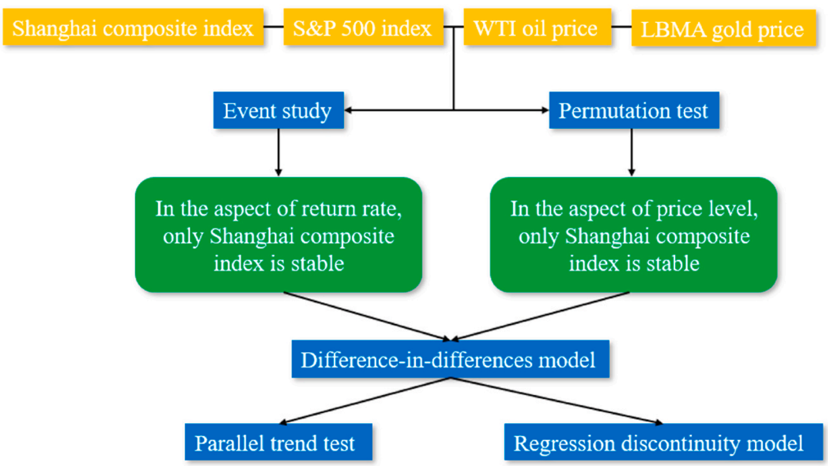

Fig. 1. Flow chart of research design.

dominant modes with low frequency. However, their method requires data from the beginning of the extreme event to the end. Since the Russia-Ukraine conflict has not been terminated by our research, this method is not applicable. Sun et al. [33] proposed a novel nonlinear interval model when measuring the shocks of Trump's election to the US stock markets. By estimating the model parameters, they obtained the instantaneous shock and decay rate of Trump's election. In their model, they assume the exponential decay of the impact of extreme events on assets of interest. However, whether the reaction of the Shanghai Composite Index, S&P 500 index, WTI oil price and LBMA gold price accords with the assumption remains to be determined. Therefore, we select other methods that have been widely recognized and commonly used to obtain more reliable conclusions, such as the event study method, difference-in-differences model and regression discontinuity design. Hansen [34] considered the structural changes caused by extreme events as breakpoints in data series. He used statistical tests of the existence of breakpoints and estimation of the timing of breakpoints to study the US labor productivity. However, the method in his study cannot quantitatively measure the exact impact of extreme events. To compare the extent and intensity of different extreme events, we adopt the event study method.

3. The method and data

Before the data and methods are introduced in detail, to articulate the logic and relationship between the adopted models, an outline of the research design is given in Fig. 1. The main model in this research is the difference-in-differences model, which quantitatively measures the impact of outbreak of the Russia-Ukraine conflict on selected financial assets. The establishment of a difference-in-differences model requires a classification of selected financial assets into two groups, the control group and the treatment group. The control group includes financial assets that receive no or subtle shock by the event, while the treatment group contains financial assets significantly impacted by the event. This classification is achieved by the event study method and the permutation test, which examine the stability in the aspects of cumulative abnormal return and change in the price level, respectively. After establishing the difference-in-differences model, its validity is checked by the parallel trend test, and its robustness is tested by the regression discontinuity model, which is another popular method to measure the impact of extreme events. In general, the event study method and the permutation test pave the way for the difference-in-differences model, and the parallel trend test and the regression discontinuity model complement the difference-in-differences model. Therefore, although each model has its findings, these models form a unity.

3.1. Data and their sources

The financial assets in this study contain the Shanghai Composite Index, S&P 500 index, WTI oil price and London Bullion Market Association (LBMA) gold price. The Shanghai Composite Index and S&P 500 index can reflect the situation of the financial systems of China and the USA, which are the top 2 greatest economies in the world. Based on existing literature, oil price shocks have an extensive influence on the state economy and financial system and have attracted much research [20,21]. Many scholars regard gold as a safe haven in extreme stock market conditions [22,23], but whether the gold price can maintain a stable performance when facing the outbreak of wars remains an interesting proposition to be checked. The Morgan Stanley Capital International (MSCI) world index is also collected for usage in the regression equation of the event study model. The MSCI world index can be the global indicator and world benchmark [35–37].

The data of the Shanghai Composite Index and S&P 500 index are from www.investing.com. The series of WTI oil price are obtained from the website of the Energy Information Administration. The series of LBMA gold price AM fixes is obtained from the LBMA website. The MSCI world index is downloaded from the Wind database (https://www.wind.com.cn/). All of the above series are in daily frequency and range from January 2nd, 1991, to November 15th, 2022.

3.2. Event study method

The event study method is an approach to measuring the impact of specific economic events on financial assets and markets [38]. From the section of the literature review, it can be seen that the event study method has been widely used [39,40]. Also, the event study method is consonant with the permutation test introduced in the next subsection in that they can both examine the stability of financial assets. Therefore, the event study method is adopted in this study. The gist of the event study method involves 2 steps. First, the ordinary performance of the selected financial asset is analyzed before the event. Linear regression is conducted in this step, where the daily return of the selected financial asset is usually taken as the dependent variable, concerning some independent variables. Then, the obtained regression equation can be used to calculate the expected daily return of the asset around and after the event day, assuming that the event would not happen. Comparing the expected daily return with the actual daily return statistically, conclusions can be drawn about the event's impact on the financial asset.

In this research, the Iraq War in 2003, the Libya War in 2011 and the Russian-Ukraine conflict in 2022 are selected as the events of interest. For each event and each financial asset, an estimation window and an event window must be selected. Data during the estimation window is used to conduct linear regression to evaluate the ordinary performance of financial assets, while data during the estimation window is used for comparison between the expected performance and actual performance of financial assets around the event. Assuming that the date of the event (event day) is day 0, we select $[-70, -41]$ as the estimation window and $[-1, 5]$ as the event window. A gap is left between the estimation window and the event to better catch the normal pattern. The event window contains some days before the event day to catch the market sentiment just before the conflict and to encompass the possibility that some investors may foresee the outbreak of conflict. In practice, the choice of estimation window is a technical problem. If the window length is too short, it will fail to incorporate the whole impact of the event. However, if the window length becomes too long, the impact of other irrelevant events could be incorporated. In this research, we follow the practice of existing literature [20,23,35] to contain several days before and after the event in the estimation window. Detailed information on the estimation window and the event window is displayed in Table 1. Moreover, a timeline of events around the outbreak of selected wars is presented in Fig. 2. It can be seen that signs might occur on the day before the event day, and it is thus necessary to incorporate day −1 into the event window. It can also be seen that several landmark events occurred within the five trading days after the event. Therefore, [+1, +5] is selected as the post-event window in this paper.

$$r_{it} = \alpha_i + \beta_i MSCI_t + \varepsilon_{it}, t = T_1 + 1, \ldots, T_2 \tag{1}$$

In the estimation window, the linear regression (1) is carried out to estimate the parameters α_i and β_i to obtain the regular historical pattern of the asset [35], where the index i refers to different assets, the index t refers to time, and T_1, T_2 refer to the left bound and the right bound of the estimation window. $MSCI_t$ stands for the MSCI world index at day t, and $r_{it} = 100 \times (\log(p_{it}) - \log(p_{it-1}))$ is the return rate of asset i at day t.

$$\hat{r}_{it} = \hat{\alpha}_i + \hat{\beta}_i MSCI_t, t = T_3 + 1, \ldots, T_4 \tag{2}$$

Then, the calculated parameters $\hat{\alpha}_i$ and $\hat{\beta}_i$ are utilized to estimate the daily return rate $\hat{r}_{it}$ of asset i in the event window by (2), where T_3, T_4 refer to the left bound and the right bound of the event window.

Further, the abnormal return rate $AR_{it} = r_{it} - \hat{r}_{it}$, the cumulative abnormal return rate $CAR_{it} = \sum_{j=T_3+1}^{t} AR_{ij}, t = T_3 + 1, \ldots, T_4$, and the average cumulative abnormal return rate $ACAR_i = \frac{1}{T_4 - T_3} \sum_{t=T_3+1}^{T_4} CAR_{it}$ are calculated. The abnormal return AR_{it} reflects the impact of the event on financial assets. If $AR_{it} > 0$, it means that the event has a positive impact on financial asset i at day t. If $AR_{it} < 0$, it means that the event has a negative impact on financial asset i at day t. The cumulative abnormal return CAR_{it} and the average cumulative abnormal return rate $ACAR_i$ is the temporal aggregation of the impact of the event. Finally, the student-t statistics $\frac{ACAR_i}{s/\sqrt{T_4 - T_3}} \sim t(T_4 - T_3 - 1)$ is calculated for the null hypothesis: $ECAR_i = 0$, where s is the sample standard deviation of cumulative abnormal returns. A large absolute value of the student-t statistics indicates a significant impact of the event, and the sign of the student-t statistics reflects whether the overall impact is positive or negative.

3.3. Permutation test

The permutation test can be used to design test statistics when the form of the underlying probability distribution is unknown [41]. In this nonparametric method, there is no need to set a specific form of model or estimate coefficients for the time series of financial assets, which not only saves effort but also applies to more general cases and situations. The general idea is to consider a certain set of permutations of the observations to construct a probability distribution for test statistics. The reason behind this is that under the null hypothesis that no difference exists among the individuals, any permutation of the observations in the test statistics should be equally likely.

When the size of observations is small, this method can generate an exact distribution. However, when sample capacity increases, the computational complexity grows in the factorial order of magnitude since all permutations need to be calculated. Therefore, the asymptotic theorem of the permutation test is adopted in this research to examine whether the price level of a financial asset differs after the outbreak of the Russia-Ukraine conflict. Suppose that the observations before the event are $X_1, \ldots, X_m \sim i.i.d. F(x)$, and the observations on and after the event are $Y_1, \ldots, Y_n \sim i.i.d. F(x - \theta)$. The null hypothesis is $H_0 : \theta = 0$, which means no difference exists between the two populations, indicating no impact of outbreak of conflict on the financial asset. The asymptotic theorem says that under the null hypothesis, $\frac{L_N}{S} \xrightarrow{d} N(0, 1)$ [41,42], where in our context $L_N = \overline{Y} - \overline{X}, S^2 = \frac{m+n}{(m+n-1)mn} \left(S_X^2 + S_Y^2 + \frac{mn}{m+n} (\overline{Y} - \overline{X})^2 \right)$, $S_X^2 = \sum_{i=1}^{m} (X_i - \overline{X})^2, S_Y^2 = \sum_{i=1}^{n} (Y_i - \overline{Y})^2, \overline{X} = \frac{1}{m} \sum_{i=1}^{m} X_i, \overline{Y} = \frac{1}{n} \sum_{i=1}^{n} Y_i$. It can be seen that identical to the student-t statistics, the numerator of permutation test statistics takes the form of difference between averages of the two populations. A change in price level is considered to exist if the null hypothesis is rejected by large absolute values of test statistics.

3.4. Difference-in-differences model and the parallel trend test

The difference-in-differences model is an effective tool when analyzing the impact of the implementation of policies and the outbreak of events. It contains a treatment group that comprises individuals influenced by the event and a control group that is

Table 1
Detailed information on the event day, the estimation window and the event window.

Event	Event day	Estimation window	Event window
Iraq War	2003.3.20	2002.12.4–2003.1.17	2003.3.19–2003.3.27
Libya War	2011.2.16	2010.10.25–2010.12.9	2011.2.15–2011.2.28
Russia-Ukraine conflict	2022.2.24	2021.10.27–2021.12.14	2022.2.23–2022.3.3

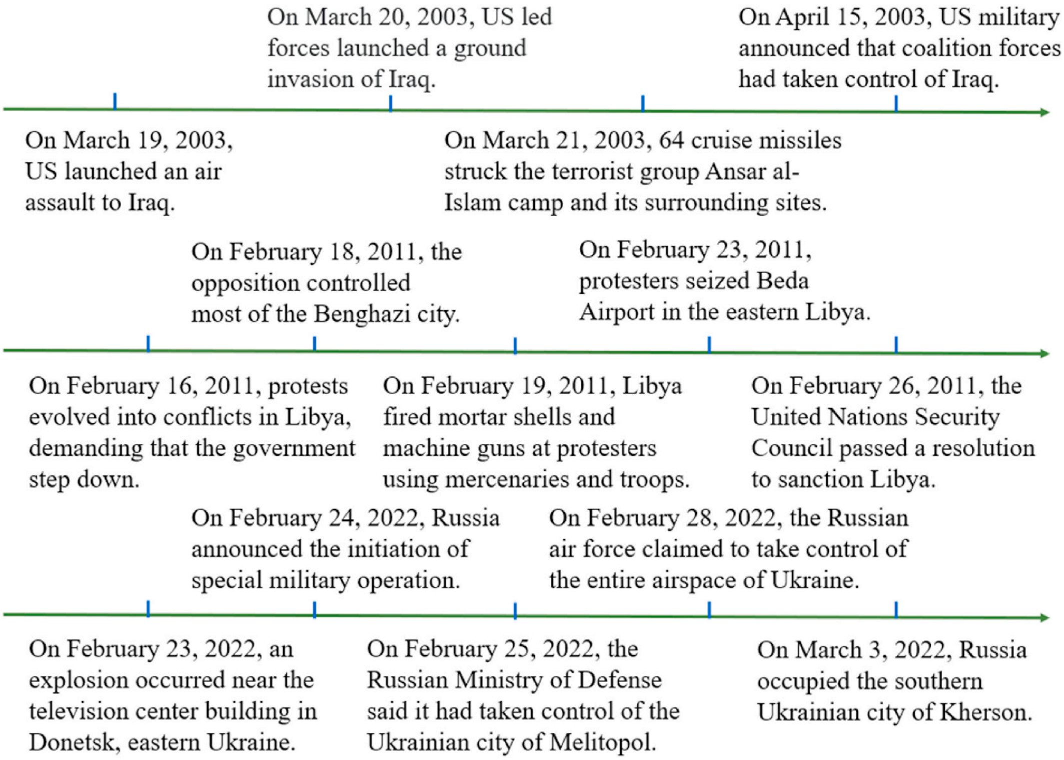

Fig. 2. Timeline of events around the outbreak of selected wars.

composed of individuals not affected by the event. In this research, the division of the control and treatment groups is based on the results of the aforementioned event study method and permutation test, which will be displayed in section 4. In the difference-in-differences model, the first difference is taken with respect to time, which stands for growth in price levels of financial assets when the Russia-Ukraine conflict broke out. The growth in the control group is regarded as natural growth, while the growth in the treatment group combines natural growth with the impact of conflict. Therefore, to separate the impact of conflict from the natural growth, the second difference is taken between the treatment group and the control group. The outcome represents the impact of the conflict.

The formula of the difference-in-differences model is $y_{it} = \beta_0 + \beta_1 dB + \beta_2 dT + \beta_3 dBdT + \varepsilon_{it}$, where $\beta_0, \beta_1, \beta_2, \beta_3$ are parameters to be estimated. dB, dT are dummy variables that stand for the group and time. $dB = 0$ if individual i belongs to the control group, while $dB = 1$ if individual i belongs to the treatment group. $dT = 0$ if time t is before the outbreak of the event. Otherwise, $dT = 1$. $dBdT$ is an intersection term that equals 1 if and only if $dB = 1$ and $dT = 1$. y_{it} stands for the outcome of interest, and in this study, it is the series of price level of financial assets. In the formula, the parameter β_3 of the intersection term is the outcome of double difference with respect to time and group, which measures the event's impact [43].

The parallel trend test plays an important role in checking the robustness of the results [44]. An essential prerequisite for applying the difference-in-differences model is the "parallel trend assumption" [45], that is, the treatment group and the control group should share a consistent trend before being impacted by the event. Only when the "parallel trend assumption" is satisfied will the first difference of the control group represent the common natural growth with respect to time. Otherwise, individuals in the treatment group and the control group have different natural growth patterns, and thus the outcome of the second difference makes no sense economically. The test establishes another regression equation, namely, $y_{it} = \beta_0 + \beta_1 dB + \beta_2 dT + \sum_{i=-p}^{q} \gamma_i dB \bullet I(t = i) + \varepsilon_{it}$, where $I(t = i)$ is an indicator variable that equals 1 if and only if time $t = i$. Otherwise, $I(t = i) = 0$. In the equation, the coefficient γ_i measures the difference in trends at time i between the treatment group and the control group. If the coefficients $\gamma_i(i < 0)$ before the event are insignificant, then the existence of a parallel trend is indicated. Furthermore, if the coefficients $\gamma_i(i \geq 0)$ on and after the event are significant, then the impact of the Russia-Ukraine conflict is confirmed.

3.5. Regression discontinuity design

Aside from the difference-in-differences model, regression discontinuity design is another method frequently used to measure the impact of a particular event [46]. In this study, it is chosen as an alternative model to confirm the robustness of the conclusions of the difference-in-differences model. Due to the high speed of news transmission in contemporary society, data current and after the outbreak of an event can be considered to be affected by the event. Therefore, the sharp regression discontinuity design is adopted in this study. The method considers the event as a breakpoint and carries out piecewise regressions for each data series. The jump between the estimated piecewise function on the event day measures the impact of the event on the data series.

Both parametric and nonparametric regression are carried out in this study. In the parametric regression, piecewise linear regression is adopted, $y_i = \alpha + \beta(x_i - c) + \delta D_i + \gamma(x_i - c)D_i + \varepsilon_i, i = 1,\ldots,n$, where c denotes the date of breakpoint and x_i denotes the date of observation y_i. In other words, $x_i - c$ is 0 on the event day, negative before then and positive afterward. D_i is a dummy variable. Specifically, $D_i = 1$ if $x_i \geq c$ while $D_i = 0$ if $x_i < c$. In parametric regression, δ measures the jump on the event day. Since parametric methods have function specification problems, nonparametric regression $f(x_i) = \sum_j y_j K\left(\frac{x_j - x_i}{h}\right)$ is also adopted for data before the event and the rest, respectively. The kernel function takes triangular kernel $K(x) = (1 - |x|)I(|x| \leq 1)$, which is commonly used, and the bandwidth h is determined by the law proposed by Imbens and Kalyanaraman [47], where x_j denotes the time.

4. Results

In this section, we present the results of the models mentioned in section 3.

4.1. Results of event study method

The cumulative abnormal returns play an important role in evaluating the impact on daily returns of outbreaks of wars. Fig. 3 displays the variation of cumulative abnormal returns of the selected financial assets. The figure constitutes 4 subgraphs that depict the cumulative abnormal returns over time of the Shanghai Composite Index, S&P 500 index, WTI oil price and LBMA gold price, respectively. In each subgraph, the solid line represents the cumulative abnormal returns around the outbreak of the Iraq war, the dashed line stands for the cumulative abnormal returns of the Libya war, and the dotted line symbolizes the cumulative abnormal returns of the Russia-Ukraine conflict.

The rightmost endpoint of each line shows the cumulative abnormal return throughout the event window and is essential in constructing test statistics of whether the average cumulative abnormal return equals zero. If the ordinate value of the rightmost endpoint is far from zero, then the test statistic tends to have a large absolute value, and the null hypothesis of zero average cumulative abnormal return is inclined to be rejected, indicating a significant impact of the outbreak of the war. From the subgraph of the Shanghai Composite Index in Fig. 3, it is shown that the rightmost endpoint of the dashed line and the dotted line have absolute values

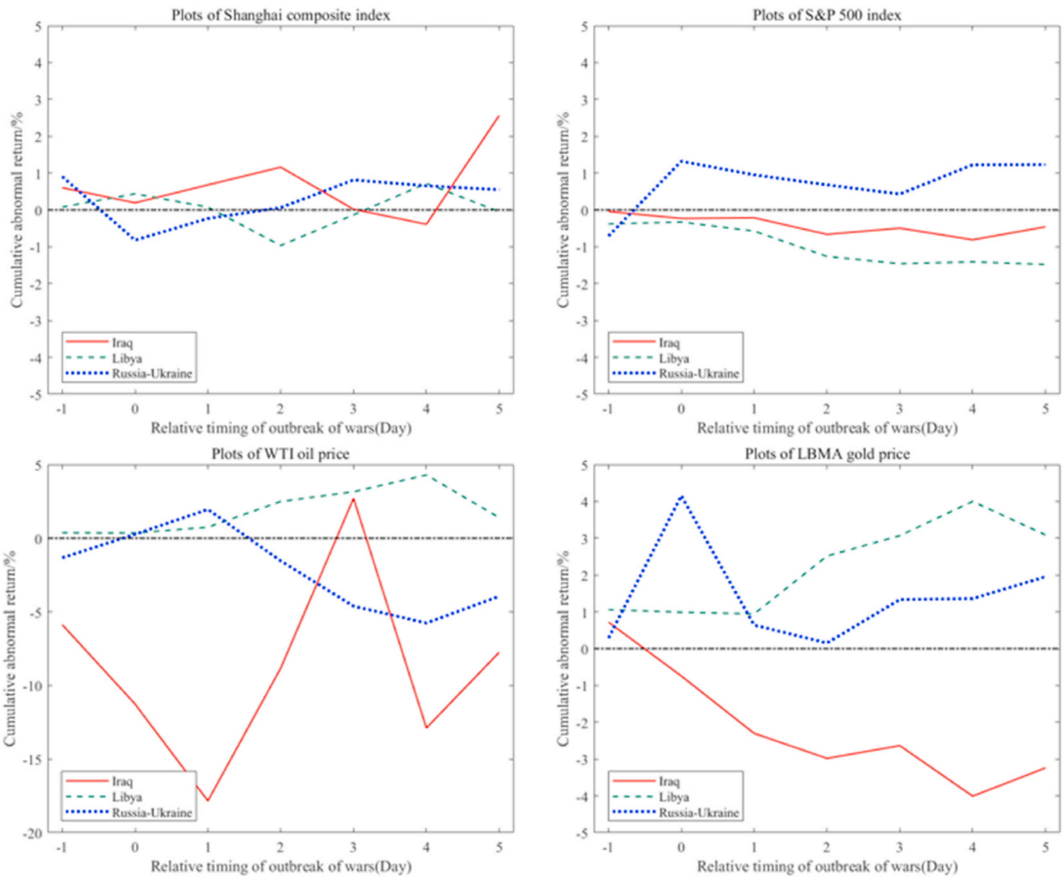

Fig. 3. Cumulative abnormal returns of the selected financial assets.

smaller than 1, which means that 2 out of the 3 wars' cumulative abnormal returns are quite small, indicating an acceptance of the null hypothesis. In contrast, in terms of the S&P 500 index, 2 out of the 3 rightmost endpoints have absolute values greater than 1, indicating a rejection of the null hypothesis. Similarly, the subgraphs of the WTI oil price and LBMA gold price indicate a tendency for rejection of the null hypothesis.

Aside from graphic analysis, statistical inference is conducted to obtain rigorous and reliable conclusions. Table 2 displays the average cumulative abnormal returns and their t-values of the selected financial assets at the outbreak of 3 wars. From Tables 2 and it can be seen that for each selected financial asset, its significance of cumulative abnormal returns shows a consistent historical pattern over all 3 wars. This finding provides strong evidence for determining the stability of each financial asset. Specifically, for the Shanghai Composite Index, it is shown that all average cumulative abnormal returns at the outbreak of those wars are insignificant, indicating that the return of the Chinese stock market is relatively stable in the face of the shock of the outbreak of wars. Possible explanations could be that the Chinese financial market is centrally controlled [48], which, to some extent, diminishes the external impact. Besides, the locations of those wars were geographically far from China, and the Chinese government took a relatively neutral standpoint when the wars happened. Therefore, the selected wars caused little panic among Chinese investors. However, except for the Shanghai Composite Index, the average cumulative abnormal returns for the S&P 500 index, WTI oil price and LBMA gold price at the outbreak of selected wars are all significant. Therefore, from the perspective of daily return, the S&P 500 index, WTI oil price and LBMA gold price are all unstable financial assets when wars take place.

Following Pandey et al. [49] and Yadav et al. [50], event windows of different lengths are further adopted to evaluate the pre-event and post-event performance of selected financial assets. Specifically, [−5,-1], [−3,-1], [0,0], [+1,+3], [+1,+5] are selected as the alternative event windows. For each financial asset, the results of the average cumulative abnormal returns are further averaged over the three wars, which is shown in Table 3. The average cumulative abnormal returns of the Shanghai Composite Index are insignificant under all of the selected windows, whereas those of the S&P 500 index, the WTI oil price and the LBMA gold price are significant in the post-event windows. Therefore, it is again indicated that the Shanghai Composite Index is relatively stable in comparison with the other financial assets. It also shows that the conclusion is robust under slight variations of event windows.

4.2. Results of permutation test

To further examine the stability of the selected financial assets around the outbreak of the Russia-Ukraine conflict, permutation tests are conducted from the perspective of change in price level, which can also function as the robustness test for the event study method. The observations included in the permutation test are [−6, 6], a slight modification of whose left and right bounds produce similar significance levels. The observations before the outbreak of conflict are taken as $X_1, \ldots, X_m$ mentioned in Section 3.3, and the observations on and after the outbreak of conflict are taken as $Y_1, \ldots, Y_n$. Then, the permutation test statistics are calculated to examine the significance of the difference between these 2 populations. Table 4 displays the p-values of permutation tests. According to Table 4, only the p-value of the Shanghai Composite Index is greater than 10 %. Therefore, conclusions can be reached that from the perspective of changes in the price level, the Shanghai Composite Index is stable, while the S&P 500 index, WIT oil price and LBMA gold price are unstable financial assets. This conclusion is in accord with the conclusion achieved by the event study method.

4.3. Results of difference-in-differences model and parallel trend test

In this section, to quantitatively analyze the impact of the outbreak of the Russia-Ukraine conflict, the difference-in-differences model is established among the selected 4 financial assets. The DID model is applied only to the Russia-Ukraine conflict because it is the most recent war among the above three wars and thus has the most influence at present. The Russia-Ukraine conflict has attracted much research interests up to now [27,28,30,31]. Also, it is considered more intelligible when the interpretation of results is focused on one specific war. In this case, the factual evidence can focus on one event, and the narrative will become more coherent. Since previous studies have confirmed the linkage among gold, oil and stock markets [51–53], it is reasonable to contain multiple of these financial assets in each difference-in-differences model due to their mutual explanatory power. According to the results of the event study method and the permutation test, the Shanghai Composite Index has stable performance in both the daily return aspect and the price level aspect, while the S&P 500 index, WTI oil price and LBMA gold price have unstable performance in both the daily return aspect and the price level aspect. Therefore, the Shanghai Composite Index is divided into the control group, and a difference-in-differences model is established for each of the remaining financial assets, respectively, which are taken as the treatment groups.

Table 2
Asset-wise average cumulative abnormal returns.

Financial assets	Iraq war	Libya war	Russia-Ukraine conflict
Shanghai Composite Index	0.691 (1.890)	0.024 (0.121)	0.278 (1.158)
S&P 500 index	−0.415*** (−4.056)	−0.983*** (−4.897)	0.734** (2.721)
WTI oil price	−8.816** (−3.639)	1.832** (3.180)	−2.135* (−2.039)
LBMA gold price	−2.169** (−3.536)	2.239** (4.783)	1.412** (2.727)

Notes: This table displays the average cumulative abnormal returns of selected financial assets at the outbreak of each selected war. The parentheses are the t-values. The asterisks *, **, and *** denote significance at 10 %, 5 % and 1 % significance levels, respectively. A significant average abnormal return indicates an unstable performance of the financial asset at the outbreak of war.

Table 3
Asset-wise average cumulative abnormal returns for different event windows.

Financial assets	[-5,-1]	[-3,-1]	[0,0]	[+1,+3]	[+1,+5]
Shanghai Composite Index	0.3532 (0.8781)	0.6041 (1.6590)	−0.5673 (−0.9673)	0.0682 (0.1963)	0.3215 (1.1276)
S&P 500 index	−0.0995 (−0.5261)	0.2888** (2.8423)	0.6911 (0.9061)	−0.5193*** (−4.6097)	−0.5227*** (−4.7363)
WTI oil price	−8.1307*** (−3.6299)	−5.1237** (−2.1857)	−1.5398 (−0.7990)	2.9913 (1.4117)	5.0940*** (2.9925)
LBMA gold price	−0.9642 (−1.1835)	−0.1916 (−0.9064)	0.6496 (0.4412)	−1.7542** (−2.5876)	−1.6268** (−2.6259)

Notes: This table presents the average cumulative abnormal returns for selected financial assets within different estimation windows. The parentheses are the t-values. The asterisks *, **, and *** denote significance at 10 %, 5 % and 1 % significance levels, respectively. [-5,-1], [-3,-1], [0,0], [+1,+3], [+1,+5] indicate the pre-event, event, and post-event windows of different lengths. A significant average abnormal return indicates an unstable performance of the financial asset at the outbreak of war.

Table 4
P-values of permutation test.

Financial assets	Shanghai Composite Index	S&P 500 index	WTI oil price	LBMA gold price
P-value	0.1006	0.0196**	5.6×10^{-4}***	6.3×10^{-4}***

Notes: This table presents the p-values of the permutation test. The asterisks *, **, and *** denote significance at 10 %, 5 % and 1 % significance levels, respectively. A significant p-value indicates a significant change in price level around the outbreak of the Russia-Ukraine conflict, which implies that the financial asset can be considered as unstable.

To determine the range of time series to be included in the difference-in-differences model, graphics of the selected financial assets are drawn. According to Fig. 4, the price of the S&P 500 index underwent a short surge after the outbreak of conflict. Therefore, [−3, 3] is chosen as the data range of the difference-in-differences model where the S&P 500 index forms the treatment group. Similarly, the data ranges for WTI oil price and LBMA gold price are [−10, 10] and [−5, 5], respectively.

Before the results of the difference-in-differences model are calculated, the issue of different magnitudes should be dealt with by

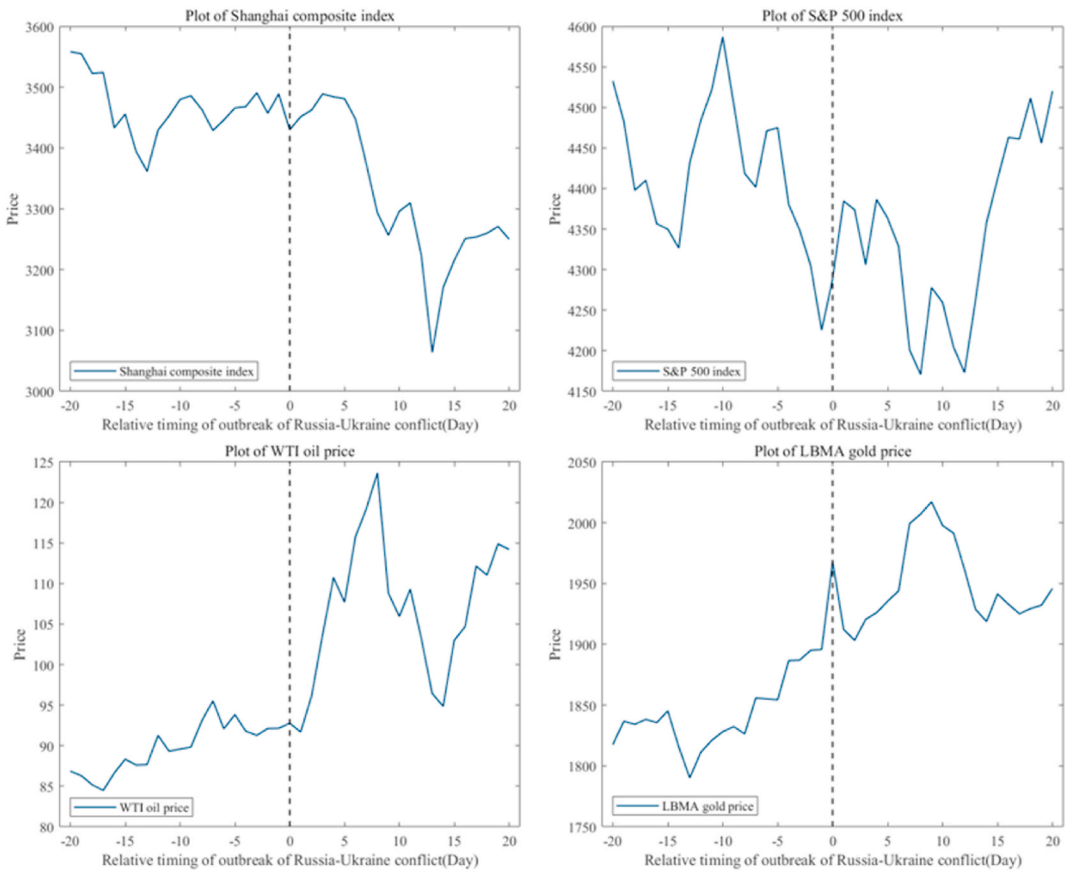

Fig. 4. Time series of the selected financial assets around the outbreak of the Russia-Ukraine conflict.

data preprocessing. In the data series selected, oil prices are lower than 100 dollars, while the others all exceed 1000. This difference in magnitudes could undermine the model's effectiveness. Therefore, 3 different techniques are adopted to handle the issue. The first technique transforms the range of each data series into the interval [0, 1] utilizing a linear function $f(x) = (x - min)/(max - min)$, where *min* and *max* refer to the minimum and maximum of the series. The second technique is frequently used in probability and statistics, which normalizes each series by subtracting its average and then dividing the series by its standard deviation. In the third technique, we simply multiply each series by a constant such that the price at the event day becomes equivalent to that of the gold price, which is a process of scaling. The gold price is selected as the reference point due to its moderate magnitude among all 4 assets. In fact, due to the nature of the difference-in-differences model and our rescaling process taken later, it can be proven that the choice of financial asset for the reference point will not influence the final result of our estimation.

Table 5 shows the estimated results of the models. The estimated coefficient of the intersection term in the difference-in-differences model is rescaled to retrieve the impact of the original order of magnitude. In column (1), the results show that the outbreak of the Russia-Ukraine conflict has a positive effect on S&P 500 index, which is significant at the 10 % level. Such a finding can be explained by the anticipation of investors that capital would flow to the US, which can be attributed to the expectation of economic sanctions issued by the US government and the European Union. In column (2), results indicate a positive impact on the WTI oil price, which is around 20$ and is significant at the 1 % level. This finding corresponds to the fact that once the conflict broke out, the export scale of crude oil from Russia and Ukraine to Europe and the US decreased heavily, diminishing the oil supply and thereby raising the oil price. In column (3), results reveal that the LBMA gold price is also promoted significantly at the 1 % level by the conflict. The estimated increment is around 50$. Gold has long been regarded as a safe haven against economic uncertainty. To avoid risk, investors tend to purchase financial derivatives linked to gold, boosting the gold price. To sum up, the S&P 500 index, WTI oil price and LBMA gold price all increased significantly once the Russia-Ukraine conflict broke out.

An essential prerequisite for applying the difference-in-differences model is the "parallel trend assumption" [45], that is, the treatment group and the control group should share a consistent trend before being impacted by the event. Therefore, a parallel trend test is conducted for each established difference-in-differences model, as shown in Fig. 5. In Fig. 5, graphs in each row stand for the results of a data preprocessing technique. Specifically, from left to right, the 3 graphs in each row represent the estimated daily treatment effect for the S&P 500 index, WTI oil price and LBMA gold price. The graphs show that before the outbreak of the Russia-Ukraine conflict, none of the daily treatment effects passes the significance test, meaning that the S&P 500 index, WTI oil price and LBMA gold price all have similar growth trends to that of the Shanghai Composite Index. This finding indicates that the former 3 financial assets would have similar growth trends to the Shanghai Composite Index after the event day in the absence of the outbreak of conflict. Another observation from the graphs is that for daily treatment effects on and after the event day, the scaling technique produces the most significant values among all data preprocessing techniques applied. This finding means that the scaling technique can best help the difference-in-differences model distinguish the impact of the Russia-Ukraine conflict on the financial assets of the treatment groups, suggesting that the results of the scaling technique should be more accurate and reliable. In summary, the parallel trend between the control group and the treatment groups is confirmed, which justifies the establishment of the difference-in-differences model.

4.4. Results of regression discontinuity design

In this subsection, the results of the regression discontinuity design are given. Each subgraph in Fig. 6 displays the fitted lines or curves of regression discontinuity design for observations before the event day and the rest, respectively. In each subgraph in the first row, the vertical line stands for the day when the Russia-Ukraine conflict broke out, and the two solid lines on the left and the right side illustrate the piecewise results of linear regression before and after the event. From these subgraphs in the first row, it can be seen that lines on the left side all have nonnegative slopes while lines on the right side all have negative slopes, indicating that prices go upwards prior to the conflict and drop after the uncertainty fades away, which is congruent with the "crisis model" [4]. In the subgraphs of the second row, the solid curves represent fitted curves before the event, while the dotted curves represent fitted curves on and after the event by nonparametric regression. Similar conclusions can be drawn.

Apart from graphic analysis, the jump at the event day is analyzed numerically. Table 6 displays the estimated jumps of the S&P 500

Table 5
Estimated results of DID model.

Financial assets	S&P 500 index	WTI oil price	LBMA gold price
Technique	(1)	(2)	(3)
Linear transformation	99.984*	23.753***	58.665***
	(1.516)	(7.293)	(2.679)
Normalization	94.663*	24.169***	56.238***
	(1.513)	(7.220)	(2.929)
Scaling	71.430*	16.462***	48.413***
	(1.418)	(7.755)	(3.999)

Notes: This table presents estimated results of the DID model of each unstable financial asset using different data preprocessing techniques. The results stand for the impact of the outbreak of the Russia-Ukraine conflict on the price levels of selected financial assets. The parentheses are the t-values. The asterisks *, **, and *** denote significance at 10 %, 5 % and 1 % significance levels, respectively.

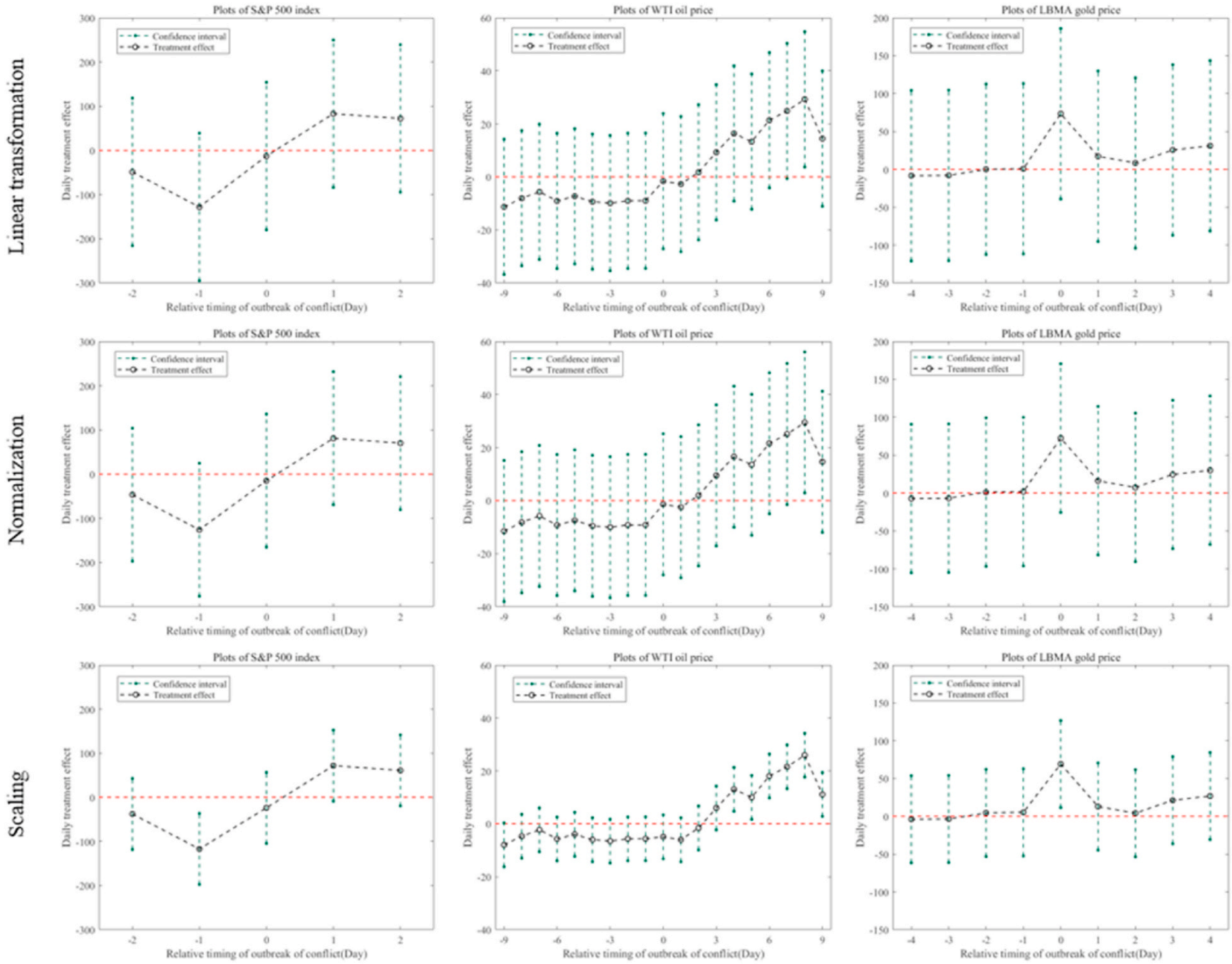

Fig. 5. 95 % confidence interval of the estimated daily treatment effect of parallel trend test.

index, WTI oil price and LBMA gold price by the parametric and nonparametric methods when the Russia-Ukraine conflict broke out. Most estimations of jumps are positive, which confirms the conclusion of the difference-in-differences model that the reactions of selected financial assets are rises in the price level. The only difference lies in the negative jump of the S&P 500 index in parametric regression. Noticing that to accurately estimate the trends before and after the outbreak of conflict, the time range of regression discontinuity design is longer than that of the difference-in-differences model, the negative jump of the S&P 500 index in the long term can be explained by the loss of confidence of US investors since the economic sanctions to Russia are partially offset by the Ruble settlement order issued by the Russian government.

5. Conclusions and policy implications

5.1. Conclusions

As an extreme geopolitical event, the outbreak of war has an extensive impact on the economic and financial system. Based on data of the Shanghai Composite Index, S&P 500 index, WTI oil price, LBMA gold price and MSCI world index, we evaluate the impact of wars on financial assets, especially the recent Russia-Ukraine conflict, using event study method, permutation test, difference-in-differences model and regression discontinuity design. The findings of this paper are summarized as follows.

First, results indicate that from historical performance under war circumstances, the Shanghai Composite Index is stable, while the S&P 500 index, WTI oil price and LBMA gold price are unstable. Specifically, the event study method reveals that the Shanghai Composite Index shows insignificant abnormal returns when wars break out, whereas the remaining three financial assets all exhibit significant abnormal returns. Meanwhile, from the perspective of changes in price level, the permutation test confirms that the change in the Shanghai Composite Index is insignificant while the others are significant. Combining the results of the above two experiments, it can be concluded that the Shanghai Composite Index has a relatively stable performance. This finding is in accord with existing research. Using time series techniques, Zhang and Sun [54] found that the Russia-Ukraine conflict increased the long-run volatility of

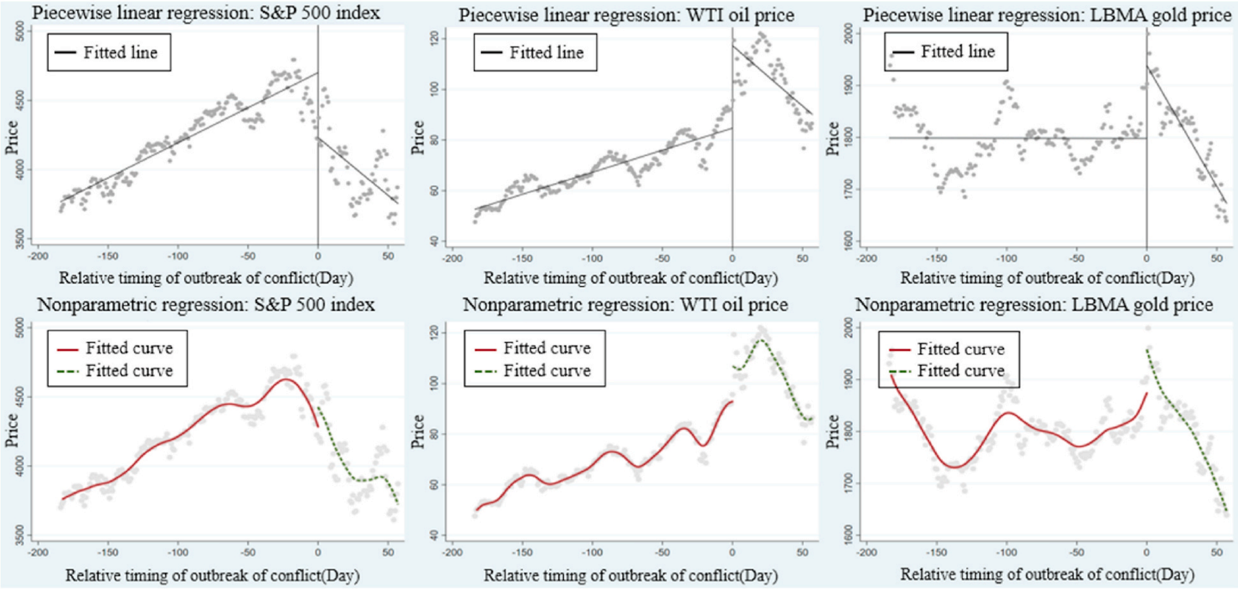

Fig. 6. Fitted curves of regression discontinuity design.

Table 6
Estimations of jump at the breakpoint by parametric regression and nonparametric regression.

	S&P 500 index		WTI oil price		LBMA gold price	
	Parametric	Nonparametric	Parametric	Nonparametric	Parametric	Nonparametric
Jump	−469.51	143.59	32.60	13.79	140.50	83.87

Notes: This table presents the estimated short-term impact of the outbreak of the Russia-Ukraine conflict on the price levels of the S&P 500 index, WTI oil price and LBMA gold price, using regression discontinuity design. Results of both parametric regression and nonparametric regression are presented.

the US market index by 185 %, while the increase of volatility of the Chinese market index was only 28 %.

Second, the outbreak of the Russia-Ukraine conflict brought significant positive shock to the S&P 500 index, WTI oil price and LBMA gold price. The rise in the S&P 500 index can be explained from the perspective of international capital flow. The geographical proximity to the battlefield of the Russia-Ukraine conflict is associated with a greater risk of the spread of war, which leads investors to shift away from the risky European markets [35]. As a result, the US stock market that is relatively safe prospers. For the oil price, a similar conclusion has been reached in the existing literature. Bae et al. [55] found that international conflicts usually generated significantly positive cumulative abnormal returns of national oil companies, and Omar et al. [56] ascribed the phenomenon to the reallocation of funds caused by precautionary, speculative and military motives. The positive reaction in gold price confirms the safe-haven attribute of gold. Triki and Maatoug [57] pointed out that gold could protect against a decline in the stock market triggered by geopolitical risk. When investors are filled with pessimistic sentiments about the performance of risky assets, they tend to take refuge in a safe investment [35]. Third, in terms of the trend of price level of unstable financial assets, an upward trend before the conflict and a downward trend after the conflict is revealed. Overall, the findings remain robust under several tests.

5.2. Implications

We emphasize the following practical implications, which provide guidance and reference for investors and policymakers. First, our findings suggest that the Shanghai Composite Index is stable, while the S&P 500 index, WTI oil price and LBMA gold price are unstable, implying that when wars happen, investors can, in general, keep their investment strategy in the Chinese stock market because previous predictions based on historical information are still reliable, while the investment strategy regarding the US stock market, oil, and gold should receive modifications, where the model equation should be reconsidered, and the model coefficients should be adjusted. On the other hand, in the face of wars, the uncertainty of the US stock market, oil, and gold can bring potential opportunity for speculation once the impact of wars on these financial assets is accurately evaluated.

Second, further analysis shows that the outbreak of the Russia-Ukraine conflict brings significant positive instantaneous shock to the S&P 500 index, WTI oil price and LBMA gold price. Therefore, the US government should be aware that the prosperity in the stock market at the beginning of the war might not be stimulated by economic growth, and thus economic policy still needs to be discreetly designed to guarantee economic development. As is mentioned in section 1, severe inflation occurred in the US after the outbreak of the Russia-Ukraine conflict. In addition, oil importers are advised to purchase oil in advance of the outbreak of wars to avoid a rise in cost due to the impact on the supply-demand balance [58]. Meanwhile, since oil price has a potential link with the exchange rate of oil-dependent economies [32], these governments should be aware of the possible impact on international trade brought by wars and issue corresponding monetary policies to alleviate the impact. Besides, central banks that plan to increase their gold reserves should accelerate the conclusion of transactions. To avoid a rise in transaction costs brought by the outbreak of war, the plan of gold procurement is suggested to be fulfilled before the war.

Third, consistent with the "crisis model" [4], we find an upward trend before the conflict and a downward trend after the conflict among the S&P 500 index, WTI oil price and LBMA gold price, which implies the purchase of short-term call options of these financial assets before the outbreak of war, as well as purchase of short-term put options after the outbreak of war. Since, for the investors, the exact date of the outbreak of war is difficult to determine, the delivery period of call options cannot be easily settled. Therefore, it is more feasible to purchase options after the war.

There are also potential limitations in this paper. First, for conciseness of conclusions and convenience of interpretation, this paper includes only 4 major financial assets in the model. Future research can consider including massive financial assets to carry out extensive analysis. Second, this paper focuses on measuring the impact of the outbreak of wars on financial assets but does not analyze the influence channels. Ascertaining the channels is a delicate task, which could be a research direction in the future with a deeper economic and financial understanding of the influence mechanism of wars. Third, this paper evaluates only the impact of the outbreak of war since the Russia-Ukraine conflict has not ended yet. The entire impact throughout the war could be analyzed after the war ends.

Data availability statement

Data associated with this study has not been deposited into a publicly available repository. Data will be made available on request.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Zhengzhong Wang: Writing – review & editing, Writing – original draft, Methodology, Investigation. **Shuihan Liu:** Validation, Methodology. **Yunjie Wei:** Writing – review & editing, Project administration. **Shouyang Wang:** Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] M. Bauer, C. Blattman, J. Chytilova, J. Henrich, E. Miguel, T. Mitts, Can war foster cooperation? J. Econ. Perspect. 30 (2016) 249–274.
[2] E. Demir, G. Gozgor, S.R. Paramati, Do geopolitical risks matter for inbound tourism? Eurasian Bus. Rev. 9 (2019) 183–191.
[3] G. Gozgor, M.C.K. Lau, Y. Zeng, C. Yan, Z.B. Lin, The impact of geopolitical risks on tourism supply in developing economies: the moderating role of social globalization, J. Trav. Res. 61 (2022) 872–886.
[4] X. Zhang, L. Yu, S. Wang, K.K. Lai, Estimating the impact of extreme events on crude oil price: an EMD-based event analysis method, Energy Econ. 31 (2009) 768–778.
[5] S.K. Agyei, Emerging markets equities? response to geopolitical risk: time-frequency evidence from the Russian-Ukrainian conflict era, Heliyon 9 (2023).
[6] A. Bossman, M. Gubareva, Asymmetric impacts of geopolitical risk on stock markets: a comparative analysis of the E7 and G7 equities during the Russian-Ukrainian conflict, Heliyon 9 (2023).
[7] W. Boungou, A. Yatie, The impact of the Ukraine-Russia war on world stock market returns, Econ. Lett. 215 (2022).
[8] V. Kumari, G. Kumar, D.K. Pandey, Are the European Union stock markets vulnerable to the Russia-Ukraine war? J. Behav. Exp. Financ. 37 (2023).
[9] V. Kumari, D.K. Pandey, S. Kumar, E.M. Xu, What do border disputes cost? Evidence from an emerging market, Int. J. Emerg. Mark. (2022), https://doi.org/10.1108/IJOEM-06-2022-0918.
[10] R. Khalfaoui, G. Gozgor, J.W. Goodell, Impact of Russia-Ukraine war attention on cryptocurrency: evidence from quantile dependence analysis, Finance Res. Lett. 52 (2023).
[11] T. Ben Hassen, H. El Bilali, Impacts of the Russia-Ukraine war on global food security: towards more sustainable and resilient food systems? Foods 11 (2022).
[12] S. Jagtap, H. Trollman, F. Trollman, G. Garcia-Garcia, C. Parra-Lopez, L. Duong, W. Martindale, P.E.S. Munekata, J.M. Lorenzo, A. Hdaifeh, A. Hassoun, K. Salonitis, M. Afy-Shararah, The Russia-Ukraine conflict: its implications for the global food supply chains, Foods 11 (2022).
[13] D. Rawtani, G. Gupta, N. Khatri, P.K. Rao, C.M. Hussain, Environmental damages due to war in Ukraine: a perspective, Sci. Total Environ. 850 (2022).
[14] S. Sarwar, M. Shahbaz, A. Anwar, A.K. Tiwari, The importance of oil assets for portfolio optimization: the analysis of firm level stocks, Energy Econ. 78 (2019) 217–234.
[15] S. Delpachitra, K. Hou, S. Cottrell, The impact of oil price shocks in the Canadian economy: a structural investigation on an oil-exporting economy, Energy Econ. 91 (2020).
[16] D.G. Baur, B.M. Lucey, Is gold a hedge or a safe haven? An analysis of stocks, bonds and gold, Financ. Rev. 45 (2010) 217–229.
[17] D.G. Baur, T.K. McDermott, Is gold a safe haven? International evidence, J. Bank. Finance 34 (2010) 1886–1898.
[18] D.K. Pandey, B.M. Lucey, S. Kumar, Border disputes, conflicts, war, and financial markets research: a systematic review, Res. Int. Bus. Finance 65 (2023).
[19] M.K. Hassan, S. Boubaker, V. Kumari, D.K. Pandey, Border disputes and heterogeneous sectoral returns: an event study approach, Finance Res. Lett. 50 (2022).
[20] A. Loutia, C. Mellios, K. Andriosopoulos, Do OPEC announcements influence oil prices? Energy Pol. 90 (2016) 262–272.
[21] Y. Wang, X. Cao, X. Sui, W. Zhao, How do black swan events go global? -Evidence from US reserves effects on TOCOM gold futures prices, Finance Res. Lett. 31 (2019) 225–231.

[22] P. Piccoli, M. Chaudhury, A. Souza, How do stocks react to extreme market events? Evidence from Brazil, Res. Int. Bus. Finance 42 (2017) 275–284.
[23] X. Gu, W. Zhang, S. Cheng, How do investors in Chinese stock market react to external uncertainty? An event study to the Sino-US disputes, Pac. Basin Finance J. 68 (2021).
[24] D. Van Geyt, P. Van Cauwenberge, H. Vander Bauwhede, The impact of the financial crisis on insider trading profitability in Belgium, J. Bus. Econ. Manag. 14 (2013) 364–385.
[25] A. Tielmann, D. Schiereck, Arising borders and the value of logistic companies: evidence from the Brexit referendum in Great Britain, Finance Res. Lett. 20 (2017) 22–28.
[26] P. He, Y. Sun, Y. Zhang, T. Li, COVID-19's impact on stock prices across different sectors-an event study based on the Chinese stock market, Emerg. Mark. Finance Trade 56 (2020) 2198–2212.
[27] S. Boubaker, J.W. Goodell, D.K. Pandey, V. Kumari, Heterogeneous impacts of wars on global equity markets: evidence from the invasion of Ukraine, Finance Res. Lett. 48 (2022).
[28] S. Boubaker, N. Nguyen, V.Q. Trinh, T. Vu, Market reaction to the Russian Ukrainian war: a global analysis of the banking industry, Rev. Account. Finance. 22 (2023) 123–153.
[29] S.G. Chortane, D.K. Pandey, Does the Russia-Ukraine war lead to currency asymmetries? A US dollar tale, J. Econ. Asymmetries. 26 (2022), e00265.
[30] S.D. Koseoglu, B.A. Mercangoz, K. Khan, S. Sarwar, The impact of the Russian-Ukraine war on the stock market: a causal analysis, Appl. Econ. (2023), https://doi.org/10.1080/00036846.2023.2188168.
[31] J.H. Xu, K. Khan, Y. Cao, Conflict and exchange rate valuation: evidence from the Russia-Ukraine conflict, Heliyon 9 (2023).
[32] W.Q. Duan, A. Khurshid, A. Rauf, K. Khan, A.C. Calin, How geopolitical risk drives exchange rate and oil prices? A wavelet-based analysis, Energ. Source. Part B. 16 (2021) 861–877.
[33] Y. Sun, K. Qiao, S. Wang, Uncertainty shocks of Trump election in an interval model of stock market, Quant. Finance 21 (2020) 865–879.
[34] B.E. Hansen, The new econometrics of structural change: dating breaks in US labor productivity, J. Econ. Perspect. 15 (2001) 117–128.
[35] D.E. Diaconasu, S.M. Mehdian, O. Stoica, The reaction of financial markets to Russia's invasion of Ukraine: evidence from gold, oil, bitcoin, and major stock markets, Appl. Econ. Lett. 30 (2022) 2792–2796.
[36] C.S.F. Ho, N.A. Abd Rahman, N.H.M. Yusuf, Z. Zamzamin, Performance of global Islamic versus conventional share indices: international evidence, Pac. Basin Finance J. 28 (2014) 110–121.
[37] T. Naccache, Oil price cycles and wavelets, Energy Econ. 33 (2011) 338–352.
[38] N. Bloom, The impact of uncertainty shocks, Econometrica 77 (2009) 623–685.
[39] X. Gu, W.Q. Zhang, S. Cheng, How do investors in Chinese stock market react to external uncertainty? An event study to the Sino-US disputes, Pac. Basin Finance J. 68 (2021).
[40] R. Hudson, A. Urquhart, War and stock markets: the effect of World War Two on the British stock market, Int. Rev. Financ. Anal. 40 (2015) 166–177.
[41] A. Wald, J. Wolfowitz, Statistical tests based on permutations of the observations, Ann. Math. Stat. 15 (1944) 358–372.
[42] G.E. Noether, On a theorem by wald and wolfowitz, Ann. Math. Stat. 20 (1949) 455–458.
[43] B. Lin, X. Li, The effect of carbon tax on per capita CO2 emissions, Energy Pol. 39 (2011) 5137–5146.
[44] L. Li, Q. Chen, Y. Wang, J. Wu, X. Jia, Mechanisms of high-speed railways' reducing industrial pollution: regulations and officials' political promotion incentives, Clean Technol. Environ. Policy 24 (2022) 1469–1485.
[45] Z. Qiao, Z. Li, Do foreign institutional investors enhance firm innovation in China? Appl. Econ. Lett. 26 (2019) 1125–1128.
[46] J. Zhang, Estimates of the returns to schooling in Taiwan: evidence from a regression discontinuity design, Appl. Econ. Lett. 27 (2019) 533–538.
[47] G. Imbens, K. Kalyanaraman, Optimal bandwidth choice for the regression discontinuity estimator, Rev. Econ. Stud. 79 (2012) 933–959.
[48] M. Leippold, Q. Wang, W. Zhou, Machine learning in the Chinese stock market, J. Financ. Econ. 145 (2022) 64–82.
[49] D.K. Pandey, M.K. Hassan, V. Kumari, R. Hasan, Repercussions of the Silicon Valley Bank collapse on global stock markets, Finance Res. Lett. 55 (2023).
[50] M.P. Yadav, A.M. Rao, M.Z. Abedin, S. Tabassum, B. Lucey, The domino effect: analyzing the impact of Silicon Valley Bank's fall on top equity indices around the world, Finance Res. Lett. 55 (2023).
[51] N. Benlagha, S. El Omari, Connectedness of stock markets with gold and oil: new evidence from COVID-19 pandemic, Finance Res. Lett. 46 (2022).
[52] E. Bouri, A. Jain, P.C. Biswal, D. Roubaud, Cointegration and nonlinear causality amongst gold, oil, and the Indian stock market: evidence from implied volatility indices, Resour. Pol. 52 (2017) 201–206.
[53] U. Akkoc, I. Civcir, Dynamic linkages between strategic commodities and stock market in Turkey: evidence from SVAR-DCC-GARCH model, Resour. Pol. 62 (2019) 231–239.
[54] Y.M. Zhang, Y.R. Sun, Did US and Chinese investors respond differently to the exogenous shocks from COVID-19 and the war in Ukraine? Int. Rev. Financ. Anal. 88 (2023).
[55] J.Y. Bae, Y. Lee, E. Heo, Effects of the Middle East conflicts on oil company returns, Energ. Source. Part B. 12 (2017) 243–249.
[56] A.M.A. Omar, T.P. Wisniewski, S. Nolte, Diversifying away the risk of war and cross-border political crisis, Energy Econ. 64 (2017) 494–510.
[57] M.B. Triki, A. Ben Maatoug, The GOLD market as a safe haven against the stock market uncertainty: evidence from geopolitical risk, Resour. Pol. 70 (2021).
[58] Q. Zhang, K. Yang, Y. Hu, J. Jiao, S. Wang, Unveiling the impact of geopolitical conflict on oil prices: a case study of the Russia-Ukraine War and its channels, Energy Econ. 126 (2023).