



# Is the Chinese crude oil spot price a good hedging tool for other crude oil prices, and in special for the main Russian oil benchmarks and during international sanctions?

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## ABSTRACT

In order to deal with risk management for policy makers and potential and current investors, green bond, bitcoin and several precious metals have been proposed as safe heavens and hedges for WTI and BRENT. We show that the Chinese DAQ spot crude oil price can also be used as a hedging tool for several main benchmark oil prices such as WTI, BRENT, OMAN and in special for Russian oil indexes such as ESPO and URAL. We find that when new international sanctions to the Russian oil are announced, in general the hedge property of DAQ decreases or is not affected. However, the hedging property of the DAQ increases very significantly due to public announcements of events that are beneficial for China to increase oil imports; specially when Russia announces important increases in its oil production or there are international sanctions and price caps on seaborne Russian crude or oil products and it is publicly known that Chinese buyers obtain Russian oil at steep discounts avoiding sanctions. We show then that hedging property depends on when international sanctions are effective, or when existing sanctions are publicly known to be easily avoided by China.

## 1. Introduction

Searching for safe havens, hedges and diversifiers of crude oil, specially in extreme market conditions, is the object of a growing literature nowadays. Baur and Lucey (2010) classify a safe heaven to be uncorrelated with other assets in times of market turmoil, a hedge is uncorrelated or negatively correlated with other assets on average, and a diversifier is positively (but not perfectly correlated) with other assets on average (see also e.g. Huang et al. (2022)). Several alternative candidates have been proposed: for example gold (see e.g. Reboredo (2013) and Dutta et al. (2020)), silver (Kang et al. (2017)), palladium (Rehman et al. (2018)), bitcoin functions (see e.g. Selmi et al. (2018)), corn investments (see e.g. Hernandez et al. (2019)) and the green bond (see e.g. Huang et al. (2022) and Arif et al. (2022)). In all these papers, the North Sea BRENT (i.e., BRENT) and/or the West Texas Intermediate (i.e. WTI) are used to represent the evolution of crude oil. From the best of our knowledge, searching for hedges for alternative (different from BRENT and WTI) oil indexes such as the OMAN, or Chinese or Russian oil indexes is unknown in the literature.

There are indeed different world-wide and well known indexes of

crude oil (apart from BRENT and WTI) and many of them have different evolutions in time. For example, Bravo-Caro et al. (2020) showed several reasons why BRENT and WTI oil prices may be different, such as different transaction costs, different risk aversions, etc. Along those lines, Hammoudeh et al. (2008) analyzed the possible relationships between WTI (representative of the United States –US–), BRENT (representative of Europe, Africa and the Middle East), DUBAI (Persian Gulf) and MAYA (Mexico) oil prices. Fattouh (2010) included in the analysis the prices of BONNY LIGHT (Nigeria), BLEND (Sahara of Algeria), MAYA (Mexico), LLOYD BLEND (Canada), WTI (US), BRENT (Europe, Africa and the Middle East) and DUBAI (Persian Gulf). Mann and Sephton (2016) analyzed the prices of WTI, BRENT and OMAN (Persian Gulf) while Luo et al. (2019) considered WTI, BRENT and DUBAI. More recently, Bhanja et al. (2022) analyzed seven (TAPIS, WTI, MURBAN, BRENT, BONNY, FORCADO and OPEC) different benchmark oil prices to find out if the oil market is globalized or regionalized with daily data from 15/05/1996 to 03/07/2018. Their results showed that the analyzed oil prices are connected and there are different transmissions between them. However, WTI, BRENT and OPEC are international oil prices mainly representative of the US, United Kingdom –UK–

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and Middle East markets. On the other hand, TAPIS, MURBAN, BONNY and FORCADO respectively represent Southeast Asia, Abhu Dhabi, Nigeria and Europe. Therefore, none of them is representative of Russian and Chinese oil prices.

In relation to Chinese oil prices, most existed literatures studying Chinese crude oil spot market choose DAQING crude oil (i.e. DAQ) as a proxy of spot price (see e.g. Zhang (2013) and Jia et al. (2015)). More recently, Lee et al. (2023) have analyzed possible spillovers among the following seven indexes: BRENT, WTI, DUBAI, TAPIS, MINAS, BONNY, and DAQING. And also possible safe heavens have been found (see e.g. Li et al. (2021)) by looking at the correlations and hedging effectiveness of Chinese crude oil futures and spots since they are quite strong. However, all these previous literature does not consider the role of Russian oil benchmarks.

Ayasli et al. (2023) have shown that price of URAL crude is one of the world's most critical medium gravity crude brands and it must be considered as a very important oil price benchmark. Under the best of our knowledge, only Sahin et al. (2023) have also shown recently the existence of relationships between BRENT and DUBAI on three Russian crude oil prices: URAL, ESPO, and SOKOL. However, they did not consider relationships between Russian and Chinese oil prices and they did not search explicitly for possible hedges and safe heavens.

Following the 2014 Russian annexation of Crimea, a large amount of countries (including the US and the European Union -EU-) imposed international sanctions against Russia (see e.g. Tuzova and Qayum (2016) and Shapovalova et al. (2020)). In January 2022, the EU announced an extension of the sanctions until July 2022 and those sanctions were heavily expanded with Russia's invasion of Ukraine in February 24th, 2022. In March 2022, China showed opposition to sanctions against Russia. Moreover, there are numerous sources of information such as Reuters (2022) that indicate that the low Russian oil prices have increased the profits of independent Chinese refineries very significantly during 2022, and this may indicate that possible relationships between the Chinese and Russian oil indexes may exist. The situation has reached a point where during January and February 2023, Russia has been China's top crude supplier (see Reuters (2023)) and there are already studies looking for possible scenarios about how Europe can manage without the imports of Russian coal, crude oil, oil products, and natural gas (see McWilliams et al. (2023)), the consequences of different degrees of energy sanctions (see Chen et al. (2023)) and how the EU would have heavier economic costs than the US (see e.g. Cui et al. (2023)). All this supports the relevance of studying possible hedging relationships between the Chinese and Russian oil indexes together with other international benchmarks.

Therefore, this paper contributes to two different strands of the literature. *First*, we search for a hedge for crude oil (see e.g. Reboredo (2013), Arif et al. (2022) and Huang et al. (2022)), but not only for BRENT and WTI, but we propose to introduce as a novelty in relation to the literature the search also for a hedge for alternative benchmark oil indexes such as OMAN, URAL and ESPO –the DAQ oil index will be our proposed hedge-. *Second*, we also contribute to the literature on finding when international sanctions are effective or not and their consequences. Economic sanctions have been especially important in the post-World War II era (see Morgan et al. (2023)). For example, Levy (1999) showed two key obstacles for the efficacy of sanctions in South-Africa in the mid-1980s: their limited economic impact and the substantial lag between the imposition of sanctions and the political change. Chen et al. (2019) found that the impact of international sanctions is different depending on if they are unilateral or multilateral, or if they are imposed by the US or the EU. Singh et al. (2019) found that economic sanctions downplay the influence that Russia could make in the energy sector and Wang et al. (2019) showed the oil sanctions consequences on exchange rates volatility. Battaglini and Harstad (2020) also showed when sanctions are more credible and effective; and Felbermayr et al. (2020) show that sanctions are more effective when they are complete and bilateral. Béliñ and Hanousek (2021) showed that

effectiveness of Western sanctions depends on their retroactivity. More recently, Konrad and Thum (2023) showed how oil sanctions and embargoes may also be ineffective under some circumstances. Moreover, Babina et al. (2023) and Itskhoki and Mukhin (2023) found the oil sanctions consequences on Russian oil exports and exchange rates respectively. In this paper we focus -as a novelty in the literature-on the oil sanctions consequences on the hedge properties for international oil price benchmarks. Therefore, we propose to introduce, for the first time in the literature, the effects of international oil sanctions on the hedging effectiveness of oil prices. In special we study the effects of international sanctions since different expectations that those international sanctions can be producing may affect significantly the search for possible hedges, safe heavens and diversifiers, depending on when they are effective or not.

The plan of the paper is as follows. In Section 2, we describe the data and the models. Section 3 provides the empirical results and Section 4 concludes.

## 2. Data and models

### 2.1. Data

Data of daily closing spot oil prices of the “North Sea BRENT” (i.e., BRENT), the “West Texas Intermediate” (i.e. WTI), OMAN (i.e. OMAN), DAQING (i.e. DAQ), the “Eastern Siberia Pacific Ocean” (i.e. ESPO) and the URALS (i.e. URAL) price indexes, all in monetary euros, have been obtained from Thomson Reuters Datastream from 2009 to 12-02 until 2023-03-10. Wang et al. (2019) and Itskhoki and Mukhin (2023) showed the oil sanctions consequences on exchange rates and exchange rates volatility. We analyze all oil benchmark prices in monetary euros in order to remove the exchange rate effect. The reason to start our analysis in 2009-12-02 was that the Russian ESPO index only had available data from that date. Bravo-Caro et al. (2020) showed several reasons why BRENT and WTI oil prices may be different, such as different transaction costs, different risk aversions, etc. And this justifies why in this paper we analyze both indicators jointly, following previous literature such as Hammoudeh et al. (2008) and Fattouh (2010).

We also consider the OMAN index (Persian Gulf), the DAQING index and two Russian indexes: ESPO and URL. Following Zhang (2013, page 877, “the Daqing oil field is the largest in China and its crude oil output accounts for approximately 25 % of national production. Because its price represents the level of crude oil prices in China, this paper uses the Daqing crude oil spot prices as representative of Chinese crude oil prices”), Jia et al. (2015, page 589, “Daqing oil price, as the local representative crude oil spot price in China, is influenced by the oil price difference across the various import sources, especially the representative global benchmark oil prices”) and Fu et al. (2023, page 1, “Daqing Oilfield, the largest continental sedimentary oilfield in China ...”), we chose the DAQ index as the main Chinese index versus alternative ones such as Shengli or South China Sea.

Sahin et al. (2023) showed that there are three main Russian indicators: URAL, ESPO and SOKOL. However, we could not find data for the SOKOL index, so we restrict our analysis to the URAL and ESPO. Ayasli et al. (2023) showed the special relevance of the URAL index.

Fig. 1 shows the evolution of WTI spot oil prices (WTI\_S) and Fig. 2 for WTI oil returns (WTI\_R) obtained, at time  $t$ , as  $WTI_R_t = 100 \cdot \ln(WTI_S_t / WTI_S_{t-1})$ . Note that on April 20, 2020, the WTI oil spot price (WTI\_S) had a large negative value for the first time in history (see Fig. 1). We computed the BRENT returns as  $BRENT_R_t = 100 \cdot \ln(BRENT_S_t / BRENT_S_{t-1})$  and we followed the same procedure for the rest of the oil indexes. Figs. 3 and 4 show the same as Figs. 1 and 2 but now for BRENT spot prices (BRENT\_S) and returns (BRENT\_R) respectively. Figs. 5–12 show the evolution of the rest of the indexes and their corresponding returns. The standard augmented Dickey Fuller (1979) and the Kwiatkowski et al. (1992) tests provide statistical evidence in favor of the stationarity of the oil returns of the all the indexes, while there is evidence in favor of a unit root in all the analyzed oil prices.



Fig. 1. Evolution of indexes and their corresponding returns.

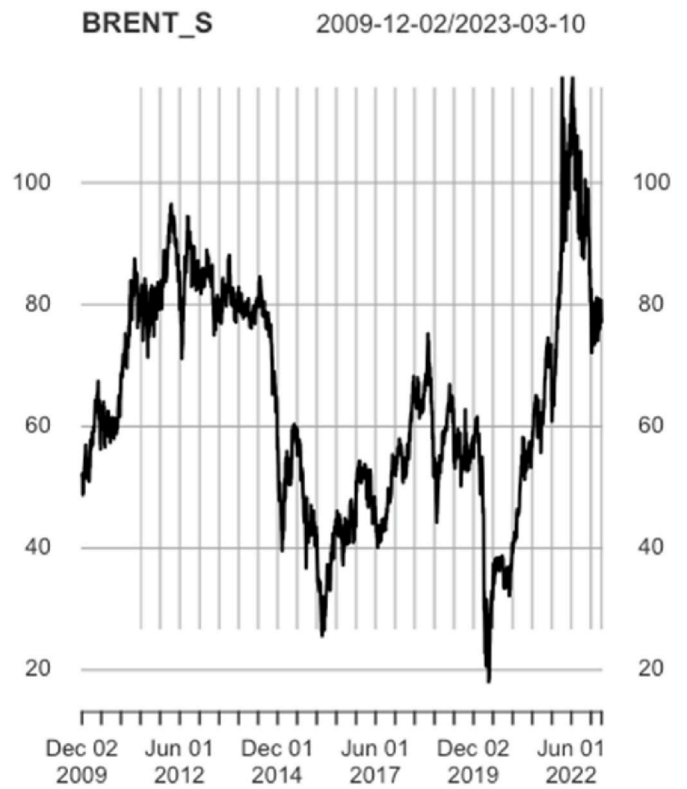


Fig. 3. Evolution of indexes and their corresponding returns.

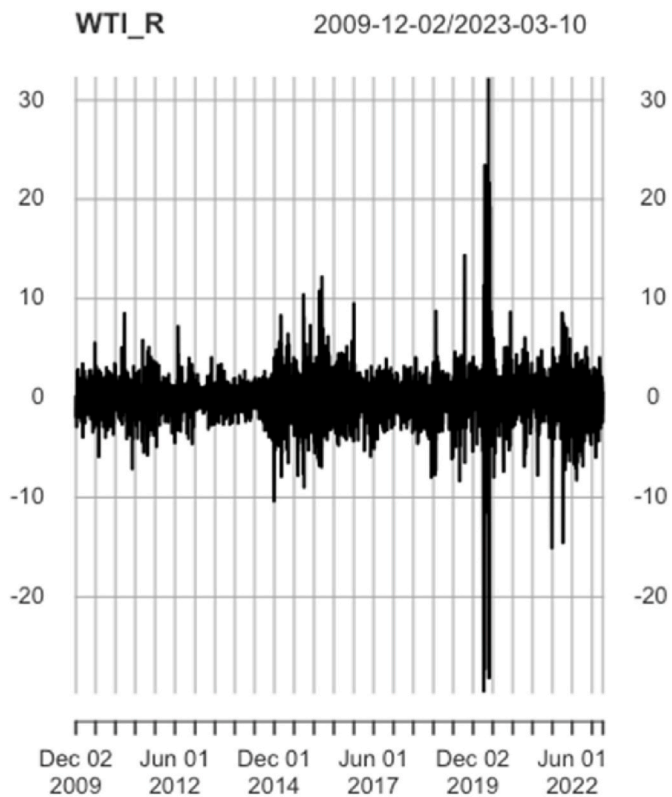


Fig. 2. Evolution of indexes and their corresponding returns.

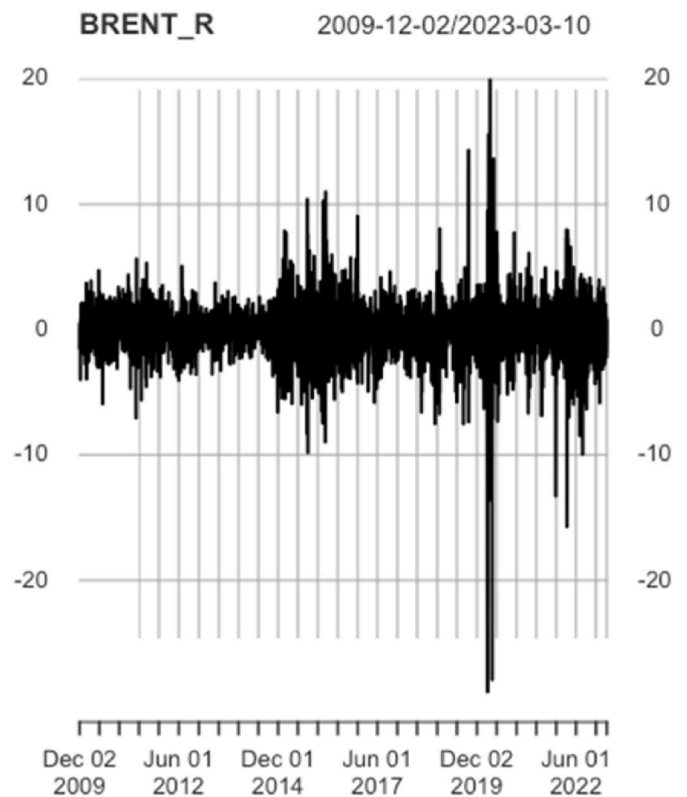


Fig. 4. Evolution of indexes and their corresponding returns.



Fig. 5. Evolution of indexes and their corresponding returns.



Fig. 7. Evolution of indexes and their corresponding returns.

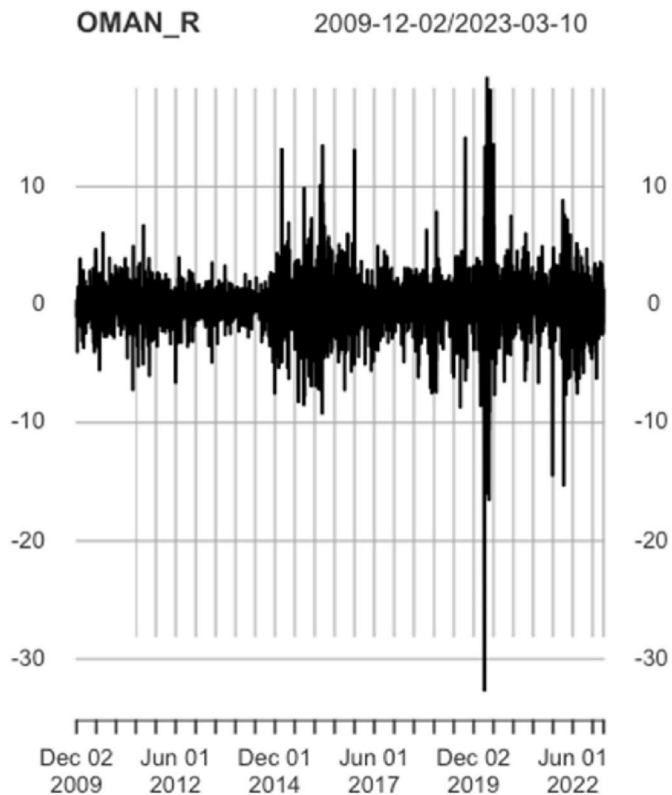


Fig. 6. Evolution of indexes and their corresponding returns.

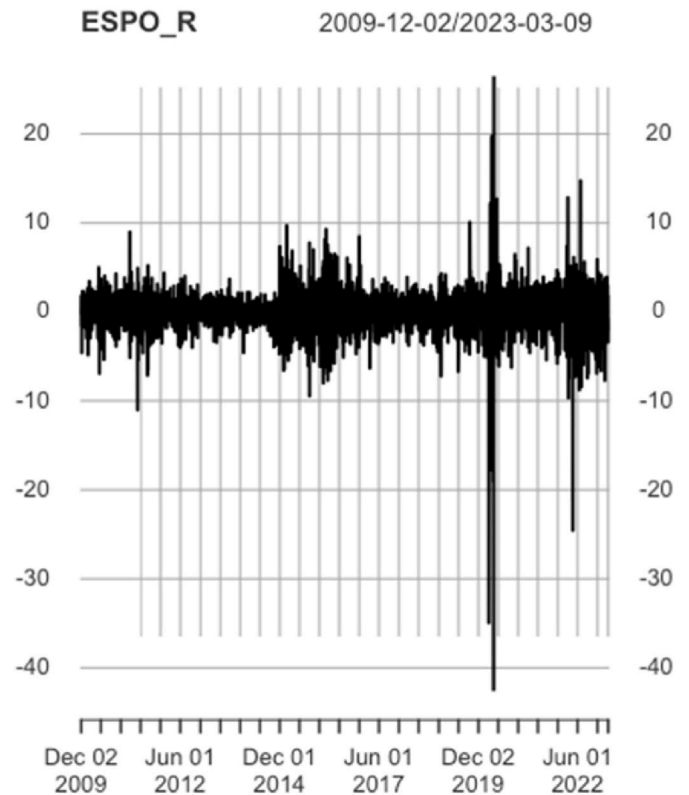


Fig. 8. Evolution of indexes and their corresponding returns.



Fig. 9. Evolution of indexes and their corresponding returns.



Fig. 11. Evolution of indexes and their corresponding returns.

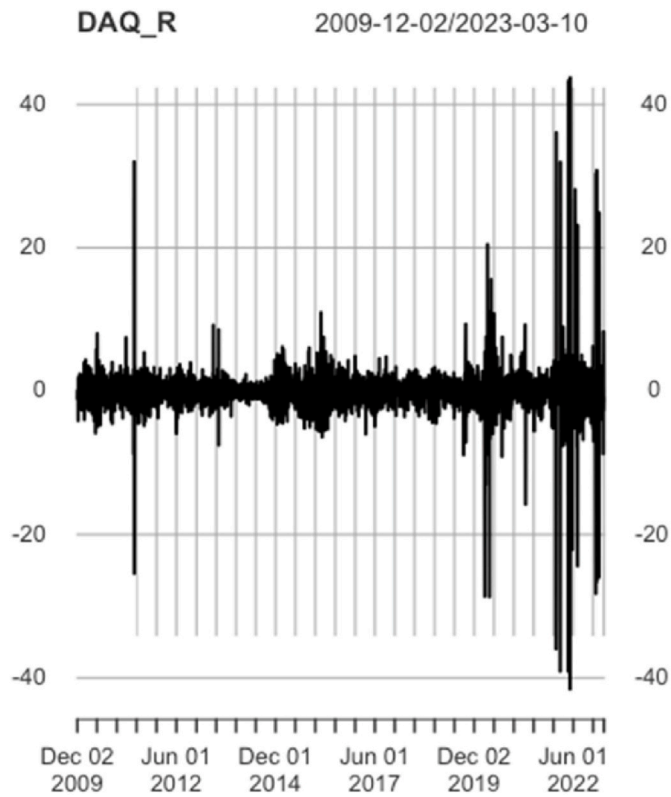


Fig. 10. Evolution of indexes and their corresponding returns.

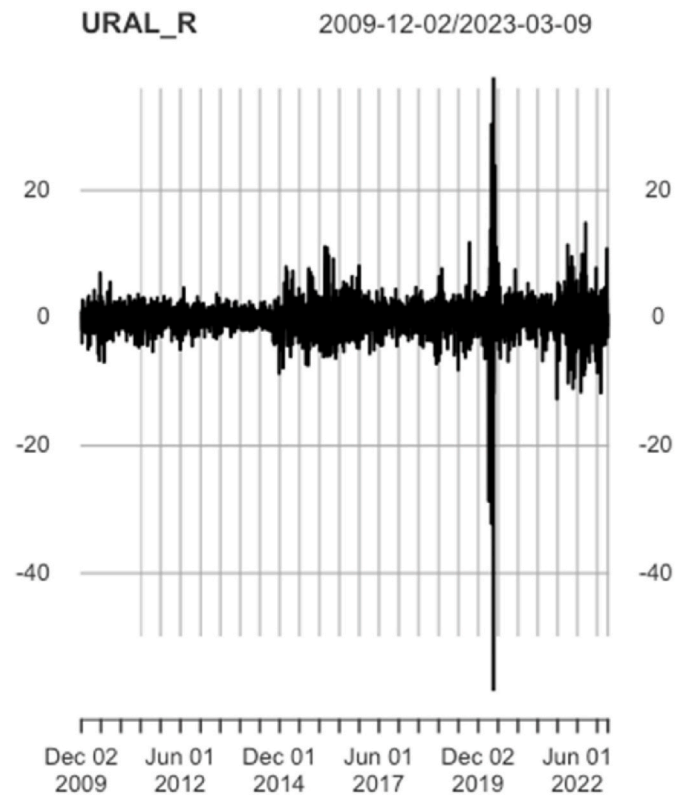


Fig. 12. Evolution of indexes and their corresponding returns.

Table 1 shows the summary statistics of the analyzed oil returns. It is possible to observe how all time series share mainly the same patterns in all periods. We can highlight the high variability of the Chinese DAQ index and the high kurtosis of the URAL index. Table 2 shows the correlations for all oil returns. As expected, the WTI, BRENT and OMAN indexes are highly correlated. On the other hand, the two Russian indexes have very low correlation with the WTI, BRENT and OMAN. And the most interesting stylized fact is the negative correlation of the DAQ index with all the rest of the indexes, being the most negative correlation with the URAL index. This negative correlation will be consistent with the dynamic correlation study that we will carry out in the following section.

2.2. The DCC model

Generalized Autoregressive Conditional Heteroskedastic (GARCH) type models (see for example Engle (2002), Bollerslev (1986), Iglesias and Linton (2007), Corradi and Iglesias (2008) and Dahl and Iglesias (2021, 2022)) are widely used nowadays to model oil volatility (see e.g. Iglesias and Rivera-Alonso (2022)). The generalization to Multivariate GARCH models (see e.g. Bauwens et al. (2006) for an extensive review) allow also to study jointly the relationships between the volatilities and co-volatilities of several markets. One of the most widely used and well-known multivariate-GARCH model is the Dynamic Conditional Correlation (DCC) GARCH model, proposed originally by Engle (2002), and given by

$$y_t = \mu + \pi y_{t-1} + \varepsilon_t \tag{1}$$

with

$$\varepsilon_t = H_t^{1/2} \eta_t \tag{2}$$

and where  $y_t = (R_{1t}, R_{2t}, \dots, R_{Nt})'$  is a vector of N returns,  $\mu = (\mu_1, \mu_2, \dots, \mu_N)'$  is a conditional mean vector, for example an autoregressive process of order 1 (AR(1)) can be allowed in the mean equation given by (1) and  $\eta_t$  is an independently and identically distributed vector error process. Moreover, the conditional covariance matrix is represented by

$$H_t = D_t R_t D_t \tag{3}$$

and the elements of  $D_t$  are written as different types of univariate GARCH models as

$$D_t = \text{diag} \left\{ \sqrt{h_{i,t}} \right\} \tag{4}$$

with for example  $h_{i,t} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t-1}$  for each of the N returns in

Table 1  
Descriptive statistics: From 2009 to 12-02 until 2023-03-09.

Summary	WTI_R	BRENT_R	OMAN_R	ESPO_R	URAL_R	DAQ_R
Mean	0.016	0.014	0.006	0.004	0.015	0.037
Variance	7.021	5.120	5.938	5.891	7.613	9.375
Minimum	-29.646	-29.000	-32.777	-34.942	-32.183	-41.779
Maximum	32.277	20.049	19.335	26.527	30.342	43.955
Std. dev	2.650	2.263	2.437	2.427	2.760	3.062
Kurtosis	27.530	15.140	18.640	25.720	67.080	25.010
Skewness	0.120	-0.470	-0.450	-0.790	1.480	-0.420

Table 2  
Correlation matrix from 2009 to 12-02 until 2023-03-09.

Correlations	WTI_R	BRENT_R	OMAN_R	ESPO_R	URAL_R	DAQ_R
WTI_R	1.000	0.897	0.825	0.3619	0.3154	-0.042
BRENT_R	0.897	1.000	0.902	0.336	0.334	-0.047
OMAN_R	0.825	0.902	1.000	0.313	0.313	-0.045
ESPO_R	0.362	0.336	0.313	1.000	0.471	-0.034
URAL_R	0.315	0.334	0.313	0.471	1.000	-0.065
DAQ_R	-0.042	-0.047	-0.045	-0.034	-0.065	1.000

case GARCH(1,1) models are used. Following Jensen and Rahbek (2004a, 2004b), the asymptotic normality of the Quasi-Maximum-Likelihood (QML) estimator (and to guarantee the positivity of the conditional variance) requires the positivity of  $\omega$ ,  $\alpha$  and  $\beta$  (see also McAleer (2014)). Note that other models of the family of univariate-GARCH models may be used in equation (4), such as the Threshold GARCH (TGARCH) model of Zakoian (1994), the Exponential GARCH (EGARCH) of Nelson (1991) or the GJR-GARCH model of Glosten et al. (1993).

Also a time-dependent conditional correlation matrix is defined as

$$R_t = (\text{diag} Q_t)^{-1} Q_t (\text{diag} Q_t)^{-1} \tag{5}$$

and the symmetric positive matrix  $Q_t$  is given by

$$Q_t = (1 - \gamma_1 - \gamma_2) \bar{Q} + \gamma_1 \eta_{t-1} \hat{\eta}_{t-1} + \gamma_2 Q_{t-1} \tag{6}$$

with  $\bar{Q}$  being the unconditional correlation matrix of standardized residuals. All DCC models were estimated by QML (we also showed that the results were robust when assuming a fat tail distribution for the innovations). From the estimated results, we can obtain the evolution of the dynamic conditional correlations. The DCC-GARCH model has been widely used to search for hedges and safe heavens in the literature (see e.g. Kinatader et al. (2021), Huang et al. (2022) and Mohamad (2022) as examples).

It is important to mention that there are alternative methods to using the DCC-GARCH model (as in Kinatader et al. (2021), Huang et al. (2022) and Mohamad (2022)), such as quantile regression (see Baur and Hoang (2021)) or quantile coherency as in Kołodziejczyk (2023). Following Kołodziejczyk (2023), "... quantile coherency has an advantage over traditional correlation, since even uncorrelated variables may reveal dependence when analyzed in different parts of the joint distribution, or at different frequencies that correspond to different investment horizons ...". However, since the main objective of our paper is not only to find out possible hedging properties but also when international sanctions may affect them, dynamic correlation figures from the DCC-GARCH model are especially useful in our case. Therefore, we employ the DCC-GARCH model, although checking the robustness of our results with alternative methodologies such as quantile regression or quantile coherence, is left for future research.

3. Empirical findings

Our main objective is to analyze the joint evolution of ESPO, URAL (representatives of the Russian market), DAQ (representative of the Chinese market), OMAN, BRENT and WTI spot oil price indexes from

2009 to 12-02 until 2023-03-10. Following Huang et al. (2022), we include the extreme event periods of Russia’s war outbreak with Ukraine and the declaration of COVID-19 as a pandemic.

Table 3 shows the estimation results of three DCC models (Models 1, 2 and 3) by QML, and they are robust to the inclusion of the two Russian indexes. Model 2 is given by equations (1)–(6) where  $y_t$  is composed by the returns of WTI, BRENT, OMAN, DAQ, ESPO and URAL. Models 1 and 3 remove URAL and ESPO from  $y_t$  in relation to Model 2 respectively. Since the results from using Models 1, 2 and 3 are robust, we chose Model 2 in order to obtain the dynamic correlations for the six indexes.

We have chosen finally a GARCH(1,1) structure for the components of the  $D_t$  matrix in equation (4) and an AR(1) in equation (1) in order to remove the autocorrelation in the estimated residuals and following the Akaike Information Criteria (the results are also consistent when using the Bayes Information Criteria). Alternative models to the GARCH(1,1) in equation (4) (such as the TGARCH, GJR-GARCH and the EGARCH) and to the AR(1) in (1) (of the family of ARMA –Autoregressive and Moving Average-models) were tried, but they were not chosen by the Akaike Information Criteria and standard-t tests. As shown in Alexander (2008), “GARCH volatilities with relatively high  $\alpha$  and relatively low  $\beta$  are more “spiky” than those with relatively low  $\alpha$  and relatively high  $\beta$ ...”, while high  $\beta$  is related with higher persistence of the volatility (see also Iglesias and Rivera-Alonso (2022)). Our Table 3 confirms that we have high persistence of the volatility in all our analyzed indexes. However, as discussed in Carnero et al. (2004), this can also be due to the presence of extreme observations as we can observe in the high values of the kurtosis in Table 1. Note that from Table 1, URAL is the index that presents a very

different kurtosis of 67.08 from the rest of the five alternative analyzed indexes, and in Model 1 we have already shown that the results are robust if we remove URAL from the analysis, what is an indication of the robustness of our results to that high kurtosis value. In any case, assuming a fat-tail distribution for the innovations might change those estimated values (see Carnero et al. (2004)). Therefore, we have re-estimated Model 2 assuming a t-distribution for the innovations and the results are given in the column named Model 2\* in Table 3. Comparing the columns of Model 2 and Model 2\*, we check that there are only very small differences in the estimated parameters  $\gamma_1$  and  $\gamma_2$ , showing that the results are robust. Finally, we have also checked that the results were robust when using a Laplace distribution, and also if an asymmetric-DCC model (see Capiello et al. (2006)) was employed.

Since the results from using Models 1, 2, 3 and 2\* are robust, we chose Model 2 in order to obtain the dynamic correlations for the six indexes. We obtained the dynamic correlations given in Figs. 13–17. Figs. 13a–17a are Figs. 13–17 were we focus on the period from 2020 until 2023-03-09 for ease of interpretation. The results from all Figures confirm the results from Table 2, where WTI, BRENT and OMAN have very high positive dynamic correlations. On the other hand, the two Russian indexes present very low positive dynamic correlations with WTI, BRENT and OMAN, what means that the Russian benchmarks may act as their diversifiers (see e.g. Huang et al. (2022) where they show that several precious metals may act also as diversifiers of the WTI index and Arif et al. (2022) show that green bond may act as a diversifier for BRENT). URAL and ESPO present low positive dynamic correlations, indicating also possibilities of diversification between them. The

**Table 3**  
DCC estimation results from 2009 to 12-02 until 2023-03-09.

DCC (1,1)	MODEL 1	MODEL 2	MODEL 3	MODEL 2*
<b>WTI</b>				
$\mu_1$	0.022 (0.030)	0.018 (0.030)	0.035 (0.028)	0.057* (0.029)
$\pi_1$	-0.011 (0.019)	-0.016 (0.020)	-0.038** (0.018)	-0.018 (0.019)
$\omega_1$	0.110*** (0.036)	0.108*** (0.035)	0.010*** (0.029)	0.112*** (0.030)
$\alpha_1$	0.137*** (0.023)	0.137*** (0.023)	0.128*** (0.019)	0.119*** (0.016)
$\beta_1$	0.849*** (0.024)	0.849*** (0.024)	0.860*** (0.019)	0.863*** (0.018)
<b>BRENT</b>				
$\mu_2$	0.031 (0.029)	0.027 (0.029)	0.037 (0.027)	0.058** (0.027)
$\pi_2$	-0.014 (0.020)	-0.019 (0.020)	-0.041** (0.018)	-0.016 (0.019)
$\omega_2$	0.089*** (0.028)	0.089*** (0.028)	0.083*** (0.023)	0.088*** (0.026)
$\alpha_2$	0.125*** (0.020)	0.126*** (0.021)	0.116*** (0.017)	0.110*** (0.016)
$\beta_2$	0.861*** (0.021)	0.860*** (0.022)	0.871*** (0.017)	0.875*** (0.018)
<b>OMAN</b>				
$\mu_3$	0.024 (0.029)	0.019 (0.029)	0.036 (0.027)	0.058** (0.026)
$\pi_3$	-0.032 (0.020)	-0.032 (0.020)	-0.045** (0.018)	-0.035** (0.018)
$\omega_3$	0.061** (0.024)	0.060** (0.024)	0.062*** (0.021)	0.069*** (0.021)
$\alpha_3$	0.117*** (0.023)	0.118*** (0.023)	0.108*** (0.018)	0.108*** (0.017)
$\beta_3$	0.879*** (0.022)	0.879*** (0.022)	0.887*** (0.018)	0.884*** (0.017)
<b>DAQ</b>				
$\mu_4$	0.025 (0.031)	0.025 (0.032)	0.030 (0.030)	0.063** (0.027)
$\pi_4$	-0.053* (0.028)	-0.024 (0.026)	-0.057** (0.023)	-0.012 (0.019)
$\omega_4$	0.036 (0.030)	0.045 (0.041)	0.050 (0.043)	0.244* (0.137)
$\alpha_4$	0.082*** (0.018)	0.094*** (0.026)	0.098*** (0.026)	0.169** (0.070)
$\beta_4$	0.917*** (0.021)	0.905*** (0.032)	0.901*** (0.032)	0.792*** (0.084)
<b>ESPO</b>				
$\mu_5$	0.012 (0.028)	0.010 (0.029)		0.042 (0.027)
$\pi_5$	-0.033* (0.020)	-0.035* (0.020)		-0.030* (0.018)
$\omega_5$	0.048** (0.023)	0.052** (0.025)		0.059*** (0.021)
$\alpha_5$	0.103*** (0.018)	0.107*** (0.019)		0.105*** (0.015)
$\beta_5$	0.892*** (0.019)	0.888*** (0.020)		0.887*** (0.016)
<b>URAL</b>				
$\mu_6$		0.028 (0.032)	0.041 (0.033)	0.061** (0.031)
$\pi_6$		0.010 (0.019)	0.008 (0.018)	0.016 (0.018)
$\omega_6$		0.050*** (0.016)	0.046*** (0.014)	0.070*** (0.017)
$\alpha_6$		0.082*** (0.010)	0.077*** (0.009)	0.086*** (0.009)
$\beta_6$		0.912*** (0.010)	0.917*** (0.009)	0.903*** (0.009)
<b>DCC</b>				
$\gamma_1$	0.018*** (0.005)	0.015*** (0.003)	0.017*** (0.004)	0.013*** (0.002)
$\gamma_2$	0.967*** (0.012)	0.973*** (0.009)	0.965*** (0.013)	0.984*** (0.003)

Robust standard errors as in Bollerslev and Wooldridge (1992) are given in parenthesis. Model 2\* estimates Model 2 assuming a t-distribution for the innovations instead of by QML. \*\*\*, \*\*, \* denotes statistical significance at the 1%, 5% and 10% level respectively.

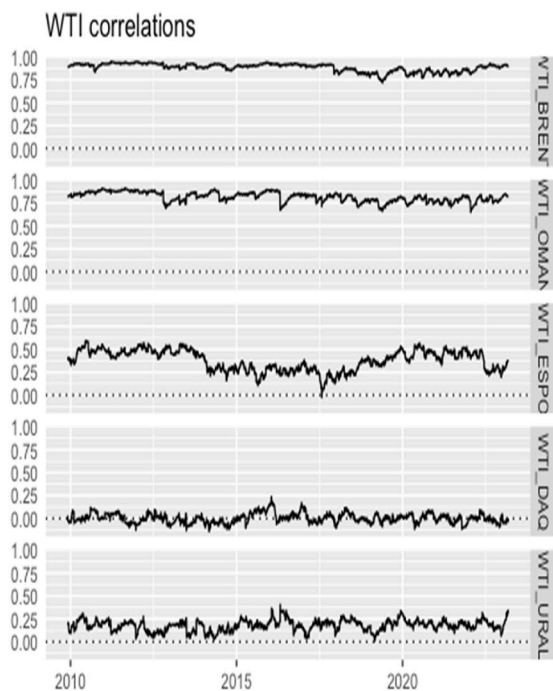


Figure 13

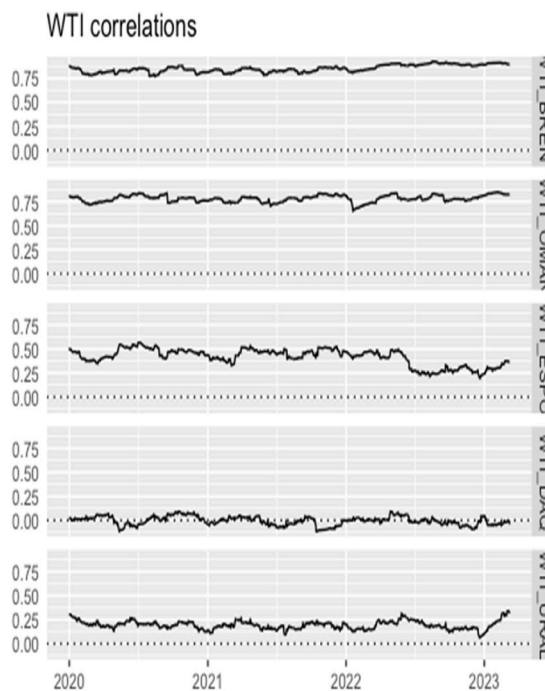


Figure 13a

Fig. 13. Dynamic correlations.

opportunities for a hedge appear when we analyze the DAQ dynamic correlations in Fig. 17 and a. The DAQ presents negative (or zero) dynamic correlations in many periods with all the other oil indexes. Fig. 18 shows a detailed analysis of Fig. 17a where ten special events are highlighted. Figs. 19–24 show the same ten highlighted events but now for the evolution of spot prices and returns of DAQ, URAL and BRENT.<sup>1</sup>

We proceed now to analyze in detail Figs. 18–24 in order to characterize the hedging procedure where DAQ is involved:

- Two black dotted lines that represent the two extreme events for which Huang et al. (2022) showed that the green bond is a hedge of the WTI index:
- 1) March 11th, 2020, when COVID-19 was declared as a pandemic by the World Health Organization (WHO) (see e.g. Iglesias (2022)). Arif et al. (2022) showed that the green bond is a diversifier for BRENT. Fig. 18 shows that the DAQ presents a hedging property for the ESPO and URAL indexes on March 11th, 2020 while it shows nearly zero correlation for the WTI, BRENT and OMAN. Figs. 19–24 show that indeed the fall in the DAQ spot index and the volatility of DAQ returns was lower than in the URAL index that day.
- 2) February 24th, 2022, when the Ukraine-Russian war started. Fig. 18 shows the DAQ was having a correlation close to zero for all indexes.
- Four dotted red lines represent events that either produce a sharp increase of the hedge property of the DAQ versus the rest of the oil benchmarks, or they start a period of negative correlation of the DAQ, specially with Russian indexes. They are announcements of events that are beneficial for China to increase oil imports, specially from Russia, when Russia announces important increases in their oil production or there are international sanctions and price caps on seaborne Russian crude (that limit the buyer pool for Russian supply, leading it to trade at deep discounts to

- international benchmarks) and it is publicly known that Chinese buyers can buy sanctioned Russian oil at steep discounts:
- 1) March 4th, 2021, when Russia indicated that it wanted to push ahead a supply increase. Russia and Kazakhstan were allowed to increase oil production while Saudi Arabia kept voluntary cuts of oil production (see CNBC (2021)). On this date, although URAL and DAQ showed zero correlation, it started a clear period of increase of the hedging property of URAL and DAQ.
- 2) October 13th, 2021, when Russia announced that Russia and OPEC + group, were doing everything possible to make sure the oil market stabilizes after the Covid-19 pandemic (see Reuters (2021)). Fig. 18 shows a very clear sharp increase of the hedging property of the DAQ with all the rest of oil indexes.
- 3) June 21st, 2022, when it is revealed that Russian URAL oil has seen a switch in flow from its traditional market of Europe to Asia and China (see Offshore-Energy (2022)). Although URAL and DAQ showed zero correlation exactly on June 21st, 2022, and from Figs. 19-20 and 22-23 we can check that DAQ and URAL returns where  $-4.87$  and  $-4.73$  respectively (i.e. very similar) that day, since then and until nowadays, URALS and DAQ have a clear hedge (negative correlation) relationship, even despite the effects of international sanctions.
- 4) February 13th, 2023, when the Russian Deputy Prime Minister announced that Russia plans to send most of its 2023 oil exports to non-sanctioning countries, including China (see SPGLOBAL (2023)), and it is revealed that Russia has been China’s top crude supplier in January and February of 2023 (see Reuters (2023)). Fig. 18 shows a very clear sharp increase of the hedging property of the DAQ with all the rest of oil indexes.
- Four dotted blue lines that represent four key dates related to international oil sanctions from the EU and USA to Russia. We see from Fig. 18 that sanction days either increase (and then DAQ decreases its effect as a hedge with the rest of the indexes) or do not affect the dynamic correlation between the DAQ and the rest of oil indexes:

<sup>1</sup> Graphs for OMAN, WTI and ESPO for spot prices and returns confirm the same results and they are available upon request from any of the authors.

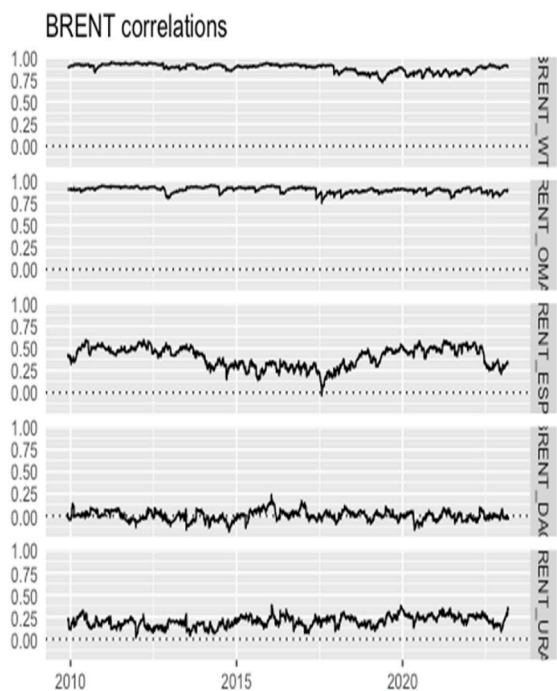


Figure 14

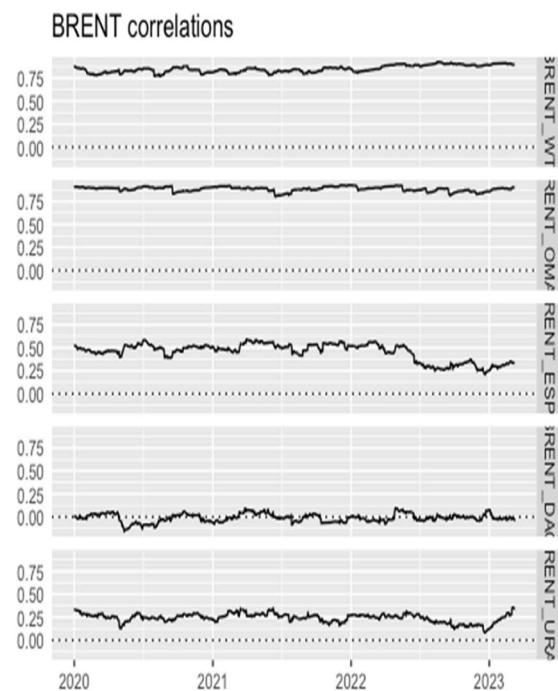


Figure 14a

Fig. 14. Dynamic correlations.

1) February 28th, 2022, when Canada banned imports of Russian crude oil and on March 8th, 2022, the US ordered a ban on imports of oil, gas and coal from Russia (see for example [Yagi and Managi \(2023\)](#)). [Fig. 18](#) shows that this sanction kept the dynamic correlation between the DAQ and the WTI, BRENTE and OMAN nearly constant.

However, it increased clearly the dynamic correlation between the DAQ and the two Russian oil indexes.  
 2) September 2nd, 2022, when finance ministers of the G7 group of nations (i.e. Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States, as well as the EU) agreed to cap the

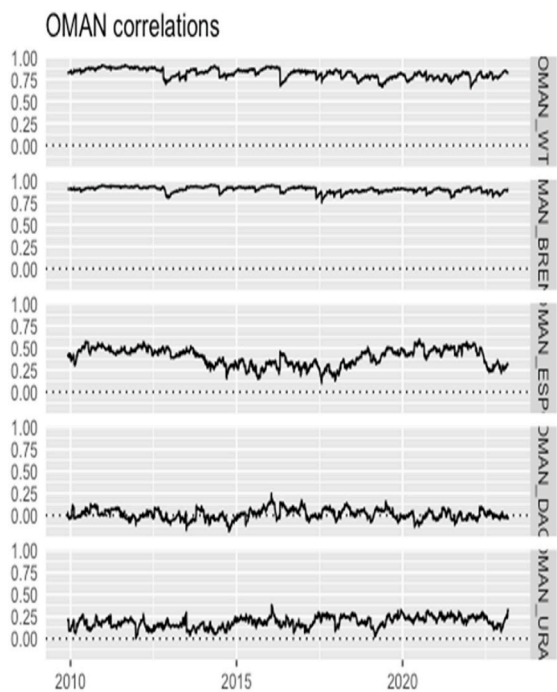


Figure 15

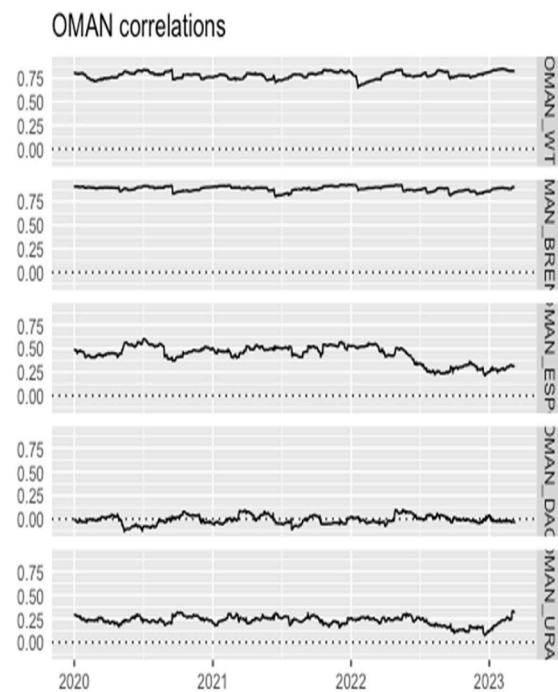


Figure 15a

Fig. 15. Dynamic correlations.

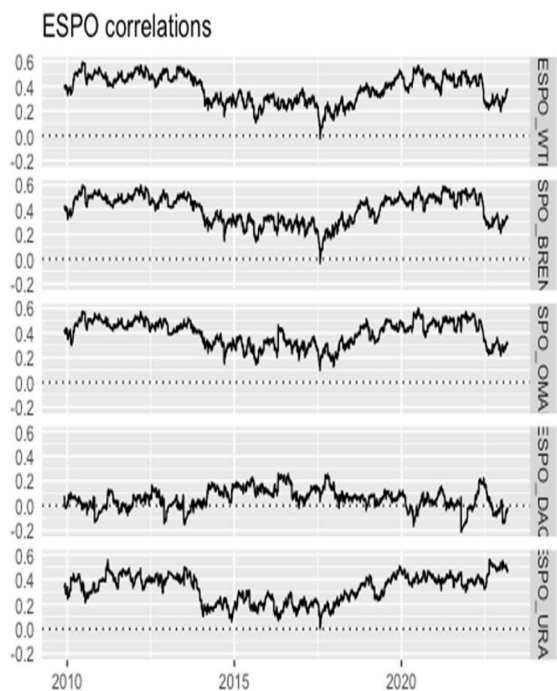


Figure 16

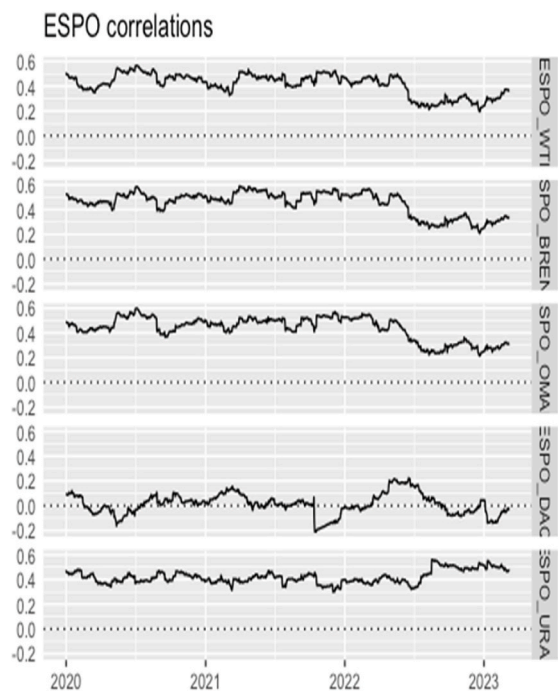


Figure 16a

Fig. 16. Dynamic correlations.

price of Russian oil and petroleum products. Gazprom (i.e., the world's largest supplier of natural gas in Russia) and China National Petroleum Corporation also signed several agreements in September 2022, including an agreement regarding the use of the Russian ruble and the Chinese yuan to pay for gas suppliers (see for example Yagi

and Managi (2023)) affecting also international perceptions about the oil sanction. Our Fig. 18 shows that this sanction kept the dynamic correlation between the DAQ and all the rest of the oil indexes nearly constant.

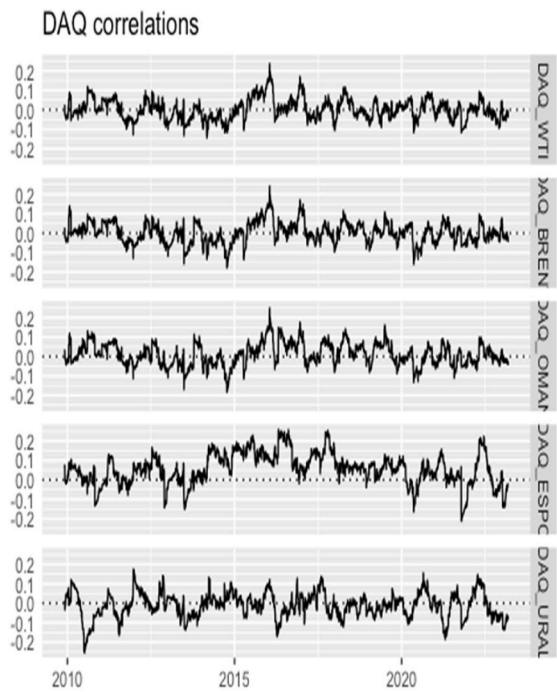


Figure 17

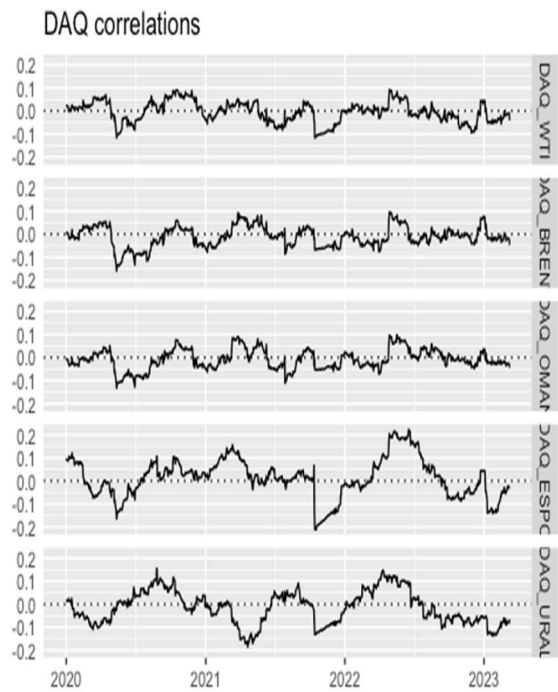


Figure 17a

Fig. 17. Dynamic correlations.

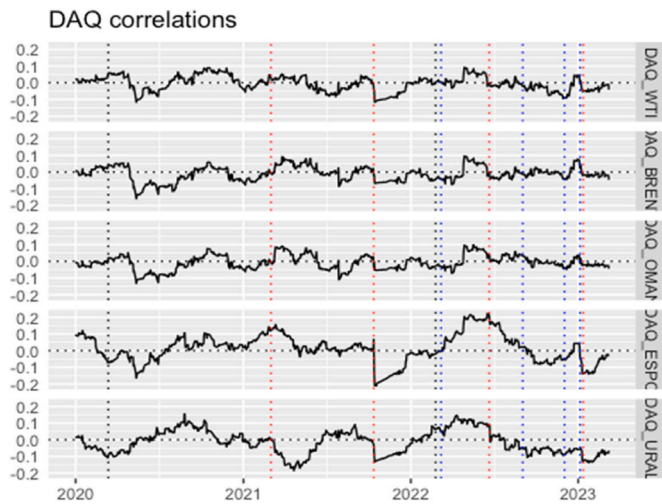


Fig. 18. Dynamic correlations.

3) December 5th, 2022, when the EU ban and G7 price cap on seaborne imports of Russian crude oil entered into force. Babina et al. (2023) have shown that with the December 5th sanction, Russia was able to redirect crude oil exports from Europe to alternative markets such as India, China, and Turkey but that export earnings were curbed substantially by the sizable discounts that Russian exporters had to accept in market segments where the EU embargo lowered demand. However, they also did not find crude oil discounts as large as those reflected in URAL prices towards the end of 2022. In particular, prices in market segments that were unaffected by lower European demand, e.g., exports from Russia’s Pacific Ocean ports, did not drop in a meaningful way and shipments did not appear to comply with

the price cap. What the EU embargo and G7 price cap have, thus, triggered is a fundamental fragmentation of the market for Russian crude oil. In relation to the hedging properties of the DAQ, our Fig. 18 shows that, out of the four studied sanctions, this was the most effective one in decreasing clearly the hedging property of DAQ with the rest of oil indexes – by increasing the DAQ dynamic correlations-

4) February 5th, 2023, when the EU imposed a limited ban and a purchase price cap on the import and transport of Russian refined petroleum products, including diesel and fuel oil. Babina et al. (2023) showed that it is significantly less feasible to redirect oil products exports away from the European market, and that this suggests that the EU embargo on oil products -which took effect on February 5, 2023- will prove to be a powerful additional tool to further curb Russian export and fiscal revenues. However, our Fig. 18 shows that the February 5th sanction did not increase the dynamic correlation of the DAQ versus the rest of the oil indexes. On the contrary, the hedging property of the DAQ versus all the rest of the oil indexes increased clearly on February 13th, 2023, when Russia announced that plans to send most of its 2023 oil exports to non-sanctioning countries, including China.

#### 4. Conclusions and policy implications

In order to deal with risk management, green bond, cryptocurrencies (bitcoin ...) and several precious metals (gold, silver, palladium ...) have been proposed as safe heavens and hedges for only WTI and BRENT in extreme market conditions. However, hedges for other alternative oil benchmarks such as OMAN, URAL and ESPO are currently unknown. Moreover, in the current context, where new international sanctions are regularly taking place to the Russian oil market, it is very important from the policy point of view and for investors to find new hedging

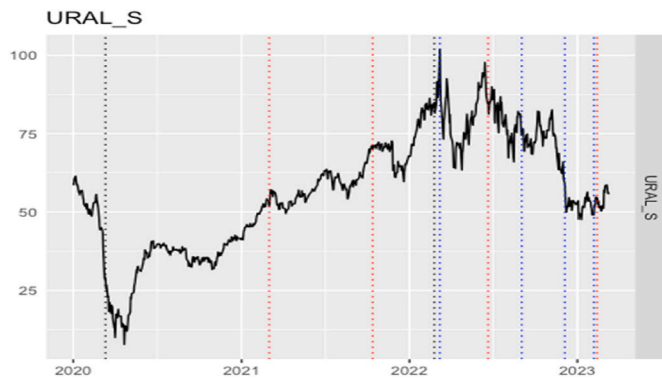


Fig. 19. Evolution of indexes and their corresponding returns.

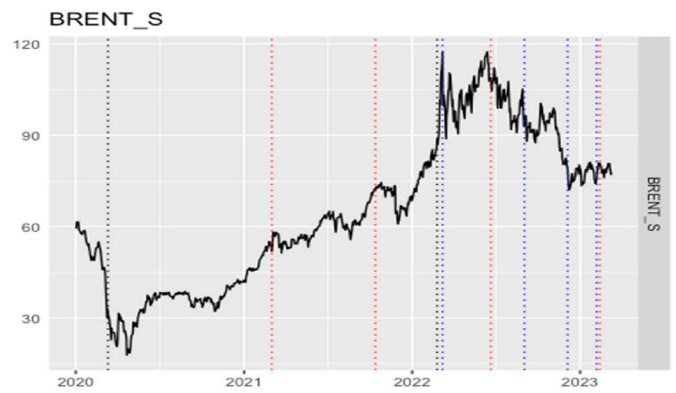


Fig. 21. Evolution of indexes and their corresponding returns.

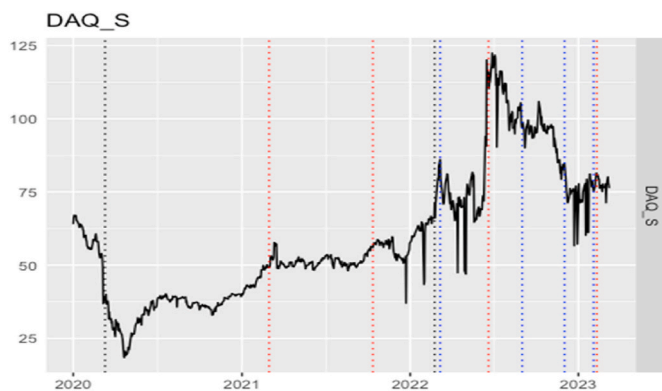


Fig. 20. Evolution of indexes and their corresponding returns.

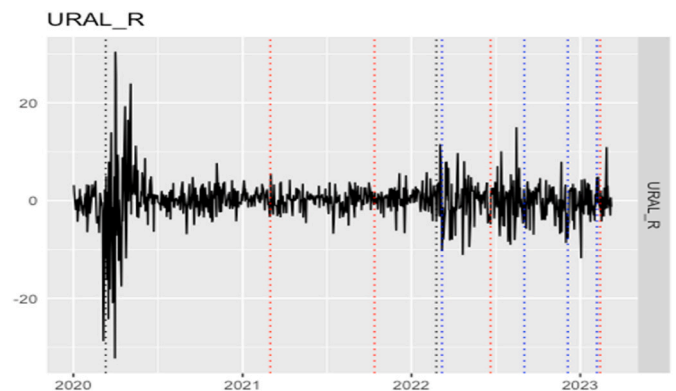


Fig. 22. Evolution of indexes and their corresponding returns.

assets and to know the consequences anytime new international oil sanctions are taking place. For example, Babina et al. (2023) and Itskhoki and Mukhin (2023) showed the oil sanctions consequences on Russian oil exports and exchange rates respectively. In this paper we focus on the oil sanctions consequences on the hedge properties for international oil price benchmarks. We show that the Chinese DAQ spot crude oil price can be used as a hedging tool for several main benchmark oil prices such as the WTI, BRENT, OMAN and in special for Russian oil indexes such as ESPO and URAL. We find that when new international sanctions to the Russia oil are announced, in general the hedge property of DAQ decreases or is not affected. However, the hedging property of the DAQ increases very significantly due to public announcements of events that are beneficial for China to increase oil imports; specially when Russia announces important increases in its oil production or there are international sanctions and price caps on seaborne Russian crude and/or on Russian oil products (that limit the buyer pool for Russian supply, leading it to trade at deep discounts to international benchmarks) and it is known that Chinese buyers obtain Russian oil at steep discounts avoiding the sanctions. Babina et al. (2023) showed that it is significantly less feasible to redirect exports away from the European market; and that this suggests that the EU embargo on oil products, which took effect on February 5, 2023, will prove to be a powerful additional tool to further curb Russian export and fiscal revenues –more powerful than that the December 5th, 2022 embargo-. We show in our paper that, in relation to the hedging properties of the DAQ index, the most effective oil sanction in decreasing the DAQ hedging property occurred on December 5th, 2022; while the February 5th, 2023 sanction did not increase the dynamic correlation of the DAQ versus the rest of the oil indexes. On the contrary, the hedging property of the DAQ versus all the rest of the oil indexes increased –by the decreasing the dynamic correlations–clearly on February 13th, 2023, when Russia announced that plans to send most of its 2023 oil exports to non-sanctioning

countries, including China. Therefore, we provide evidence that the effects of international oil sanctions –both of seaborne crude and oil products–at decreasing the hedge property of the DAQ are easily eliminated as soon as any new information is released to the general public about China’s international sanctions avoidance, and its substantial benefits by purchasing Russian oil at discounted prices (by increasing the hedge property of the DAQ index –specially with the Russian oil indexes-). We conclude therefore that hedging property depends on when international sanctions are effective, or when existing sanctions are publicly known to be easily avoided by China and other countries. Our results are consistent with previous literature such as for example Konrad and Thum (2023) where oil sanctions and embargoes may have different effects under different circumstances. Our results are also highly relevant from the point of view of public policy, risk management and for potential and current investors in the oil markets, since it is very important to know the effects on the hedging mechanisms depending on if we need a hedge for the BRENT, WTI, OMAN, URAL and/or ESPO and which are the consequences each time that new international oil sanctions take place and also when they are publicly avoided.

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## CRedit authorship contribution statement

**David Rivera-Alonso:** Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Formal analysis, Conceptualization. **Emma M. Iglesias:** Writing – review & editing, Writing – original draft, Supervision, Software, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Emma M. Iglesias reports financial support was provided by Spanish Ministry of Science and Innovation. Emma M. Iglesias reports financial support was provided by Government of Galicia.

## Data availability

The data that has been used is confidential.

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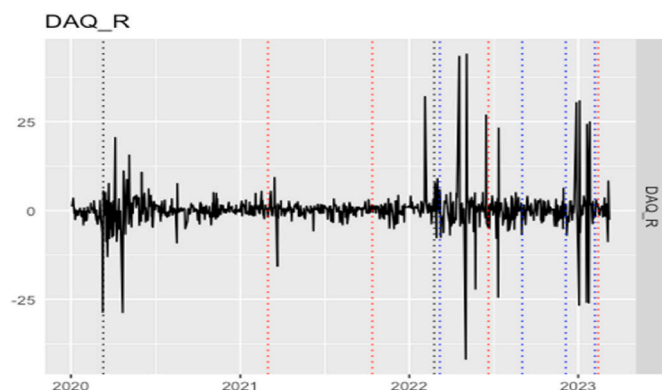


Fig. 23. Evolution of indexes and their corresponding returns.

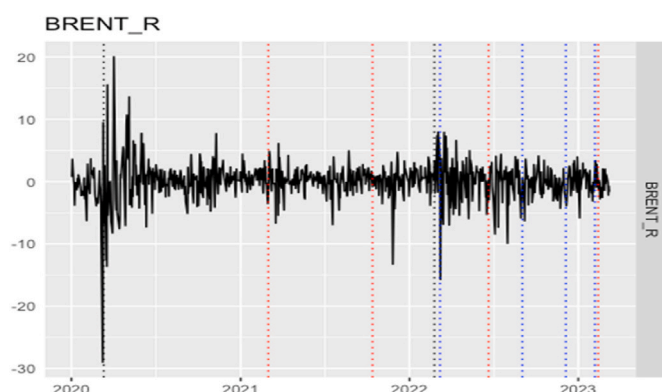


Fig. 24. Evolution of indexes and their corresponding returns.

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