Dual and single hedging strategy: a novel comparison from the direct and cross hedging perspective

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Abstract

Purpose – The purpose of this paper is to deeply study and compare the dual and single hedging strategy, from the direct and cross hedging perspective.

Design/methodology/approach – The authors not only first consider the dual hedge of integrated risks in this oil prices and foreign exchange rates setting but also make a novel comparison between the dual and single hedging strategy from a direct and cross hedging perspective. In total, six econometric models (to conduct one-step-ahead out-of-sample rolling estimation of the optimal hedge ratio) and two hedging performance criteria are employed in two different hedging backgrounds (direct and cross hedging).

Findings – Results show that in the direct hedging background, a dual hedge cannot outperform the single hedge. But in the cross dual hedging setting, a dual hedge performs much better, possibly because the dual hedge brings different levels of advantages and disadvantages in the two different settings and the superiority of the dual hedge is more obvious in the cross dual hedging setting.

Originality/value – The existing literature that deals with oil prices and foreign exchange rates mostly concentrates on their relationship and comovements, while the dual hedge of integrated risks in this setting remains underresearched. Besides, the existing literature that deals with dual hedge gets its conclusions only based on a single specific background (direct or cross hedging) and lacks deeper investigation. In this paper, the authors expand the width and depth of the existing literature. Results and implications are revealing.

Keywords Dual hedge, Single hedge, Minimum variance, Integrated risk, Correlation

Paper type Research paper

1. Introduction

Many papers have been written to demystify the interesting topic of future hedging strategies. One main strand of research involves the discussion of single and dual hedging strategy. Facing multiple sources of risk, people need to use different kinds of hedging instruments to hedge risks. The correlation between all the hedging instruments and the underlying hedged assets can affect the hedging performance of the single and dual hedging strategy. This is the reason why the dual hedging strategy needs to be deeply investigated. However, the existing study on dual hedging strategy is not comprehensive and the breadth of research needs to be broadened. Besides, the existing literature that deals with dual hedge (e.g. Lien, 2008; Morgan, 2008; Chen and Sutcliffe, 2012; Mun, 2016) only gets its conclusions based on the direct or cross hedging background separately and lacks further comparison between these two different perspectives, that is, the depth of research needs also to be deepened. In this paper, we not only first consider the dual hedge of integrated risks in this oil prices and foreign exchange rates setting but also make a novel comparison between the dual and single hedging strategy from a direct and cross hedging perspective, which greatly contribute to the existing literature in this field.

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The analysis is based on two different hedging backgrounds (direct and cross hedging), which are both important to study and interesting for comparison. The first case is direct dual hedging. The setting is the integrated risk of oil prices and the foreign exchange rate that airline companies face. There exists a direct hedging instrument that is highly correlated with the oil and foreign exchange spot price. The second case is cross dual hedging. In this setting, there is no direct hedging instrument for a spot position that is exposed to several correlated risks at the same time. We take financial institutions as an example. Suppose that they need to hedge the risk of the index, such as the AMEX oil index (XOI), which does not have a corresponding direct hedging instrument. The XOI faces risks related to the volatility of both the oil and stock markets. Therefore, crude oil futures (CL) traded on the New York Mercantile Exchange (NYMEX) and S&P 500 futures (SP) traded on the Chicago Mercantile Exchange (CME) can be used to hedge the risks from the oil and stock markets. The correlation between the hedging instrument and the hedged index is not as high as that involving the direct hedge. In this paper, six econometric models are used to conduct one-step-ahead out-of-sample rolling estimation of the optimal hedge ratio, and two hedging performance criteria are employed.

This paper contributes to the current literature in several ways. First, the existing literature that focuses on oil prices and the exchange rate mostly concentrate on their relationship and comovements. To the best of our knowledge, no research has used integrated hedging strategies to hedge oil price risk and exchange rate risk at the same time, which is very important and deserves investigation by the relevant managers and investors. Second, what is more, the existing literature deals with single and dual hedges separately in different settings, and there is no universal consensus or deeper investigation regarding the results. This paper innovatively performs a more in-depth investigation into the dual and single hedging strategy from a direct and cross hedging perspective and provides a reasonable explanation. The superiority of the dual hedge is more obvious in the cross dual hedging setting. In the first case (the direct hedging setting), the advantage of the increased explanatory capability is offset by the disadvantage of the increased cost because the explanatory capability of the original single direct hedge is already somewhat strong. In the second case (the cross dual hedging setting), the use of dual hedging instruments can better describe their correlation and easily offset the disadvantage of the transaction cost (TC) and increase overall hedging performance. In addition, to gain a deeper understanding of the dual hedging strategy and to ensure the robustness of the results, more models, (such as GO-GARCH, copula-DCC and copula-ADCC) are used to estimate the optimal hedge ratio and more hedging performance criteria (such as the innovatively developed criterion HPTC) are used to analyze different strategies' hedging performance, which have never been used for the dual hedging strategies. Altogether, this research incorporates all these aspects and conducts a comprehensive and robust analysis, and results are revealing.

The remainder of this paper is organized as follows. Section 2 presents the relevant literature review. Section 3 analyzes the setting and shows hedge ratios under different hedging strategies. Section 4 demonstrates the econometric models that this paper uses. Section 5 analyzes the data. Section 6 shows the empirical findings and robustness check. Section 7 concludes this paper.

2. Literature review

In this section, we provide a brief review of the literature related to our topic.

The existing empirical literature that deals with oil prices and foreign exchange rates concentrate on their relationship and comovements (Chen and Chen, 2007; Akram, 2009; Sari *et al.*, 2010; Lizardo and Mollick, 2010; Arouri *et al.*, 2012; Wu *et al.*, 2012; Reboredo, 2012; Basher *et al.*, 2012; Reboredo and Rivera-Castro, 2013; Salisu and Mobolaji, 2013; Brahmasrene *et al.*, 2014; Reboredo *et al.*, 2014; Mensi *et al.*, 2015; Yang *et al.*, 2017; McLeod and Haughton, 2018; Delgado *et al.*, 2018; Kim and Jung, 2018; Ji *et al.*, 2019; Kumar, 2019; Anjum, 2019; Malik and Umar, 2019). These studies have obtained mixed findings. By employing many econometric methods, such as the cointegration theory (Engle and Granger, 1987), studies show that the shock of the exchange rate can be explained by the oil price. Adopting the vector autoregressive model (Akram, 2009; Basher *et al.*, 2012), the dynamic relationship between the oil price and the foreign exchange rate is studied. Using the nonlinear Granger causality and nonlinear autoregressive distributed lag (ARDL) tests, Kumar (2019) examines the causal relation between oil prices, exchange rate and stock prices in the Indian context. Employing the vector error correction model (Krichene, 2005), it is demonstrated that the decreasing foreign exchange rate leads to an increasing crude oil price. By using threshold autoregressive (TAR) and momentum TAR (MTAR) models, McLeod and Haughton (2018) show the potential of asymmetric cointegration and multiple structural breaks. Using the vector autoregressive model (VAR)-generalized autoregressive conditional heteroskedasticity (GARCH) model (Arouri *et al.*, 2012; Delgado *et al.*, 2018), the transmission volatility spillover effect is shown. Using bivariate GARCH model, Anjum (2019) examines volatility dynamics of oil prices and the US dollar exchange rate. Conducting wavelet analysis (Reboredo and Rivera-Castro, 2013), the relationship in the pre and postcrisis period and the relationship at different time scales are investigated. Estimating copula-based models (Wu *et al.*, 2012; Kim and Jung, 2018; Ji *et al.*, 2019), the dynamic dependence is shown. Using a novel method of isolating the oil price shocks, Malik and Umar (2019) study how different sources of oil price shocks are connected to exchange rates. However, the existing literature has not yet considered the dual hedge of integrated risks in this oil prices and foreign exchange rate setting.

Most papers deal with the single hedge (e.g. Reboredo, 2013; Chen *et al.*, 2014; Wang *et al.*, 2015; Basher and Sadorsky, 2016; Billio *et al.*, 2017). Wang *et al.* (2015) use 18 econometric models to estimate the covariance parameters and then the hedge ratio, and they compare the performance between the naïve and minimum-variance hedging strategies across 24 futures markets. Basher and Sadorsky (2016) use three models to estimate the hedge ratio under the minimum-variance objective in a single cross hedge between emerging market (EM) stock prices, oil, the CBOE volatility index (VIX), gold and bonds. A few studies investigate the dual hedge (e.g. Li and Vukina, 1998; Lien, 2008; Morgan, 2008; Carbonez *et al.*, 2011; Mun, 2016). Li and Vukina (1998) show that relatively modest reduction in the variance of revenue generated by the dual hedging strategy over the single price futures hedging strategy can be explained by the low correlation between individual county level yields in North Carolina and the contract underlying yield (Iowa state average). Carbonez *et al.* (2011) propose to use two futures contracts in hedging an agricultural commodity and find that for agricultural commodities, two-contract hedges do better than the one-contract counterpart and the simple rules are the best. Mun (2016) hedges the market risk of banks with interest rate futures and currency forwards using the dynamic conditional correlation (DCC) method under the minimum-variance objective and emphasizes the importance of integrated risk management. Cui and Feng (2020) study the dual hedge with both the minimum variance and utility maximization objective and show that the composite hedge is better than the single hedge in the cross hedging context. However, they get their conclusions only based either on a direct or a cross hedging background. In this paper, we move beyond this and make a novel comparison between the dual and single hedging strategy from both direct and cross hedging perspective and results are revealing.

The dual hedging strategy is analyzed only under the minimum-variance objective, where only ordinary least squares (OLS), GARCH and DCC models are used to estimate the dual hedge ratios. Besides, research has used BEKK (Baba *et al.*, 1991), GARCH (Wang and Liu, 2016), Constant Conditional Correlation (CCC)-GARCH (Bollerslev, 1990), DCC-GARCH (Engle, 2002; Fan and Du, 2017; Deng, 2018), copula-based GARCH (e.g. Patton, 2004; Chen and Fan, 2006; Lee and Long, 2009; Luo *et al.*, 2016; Guo and Wang, 2016), copula-DCC (e.g. Kim and Jung, 2016; Berger and Uddin, 2016) and Generalized Orthogonal (GO)-GARCH (Van der Weide, 2002; Boswijk and van der Weide, 2011) models to only describe the volatility or study the single hedging strategy. However, in this paper, we first develop the copula-DCC, copula-asymmetric dynamic conditional correlation (ADCC) and GO-GARCH models into the dual hedge ratio, which may better describe the risk correlation, dependence structure and high-dimensional systems for the dual hedging strategy.

3. Settings and hedge ratios for different hedging strategies

This paper uses nonUSA airline companies as the direct hedging setting (first setting). Such companies face the risk of oil prices, as rising oil prices may increase their cost; thus, companies use CL to hedge the crude oil price risk. In addition, they face the risk of the foreign exchange rate. Because a weaker US$ can increase purchasing power and decrease their costs, while a stronger US$ may increase their costs, companies can use exchange rate futures to hedge the exchange rate risk. In this setting, the dual instruments for hedging integrated risk involves the combined use of CL and foreign exchange rate futures to hedge both the crude oil risk and the exchange rate risk at the same time. This considers all the correlations between all the spot and futures returns. In contrast, a single instrument for hedging a single risk deals only with the single correlation between the corresponding spot and futures return.

When using dual instruments to hedge integrated risk, the hedged portfolio return can be constructed as follows:

$$r_h = -r_{s1} - r_{s2} + h_1 r_{f1} + h_2 r_{f2} \tag{1}$$

where h_1 and h_2 are the hedge ratios; and r_s and r_f represent spot and futures returns, respectively. Returns are calculated as the difference in the log price between the current and previous price multiplied by 100.

Upon minimizing the portfolio variance, the hedge ratio is determined as follows:

$$h_1 = \frac{\mathrm{cov}(r_{s1}, r_{f1})\mathrm{var}(r_{f2}) + \mathrm{cov}(r_{s2}, r_{f1})\mathrm{var}(r_{f2}) - \mathrm{cov}(r_{s1}, r_{f2})\mathrm{cov}(r_{f1}, r_{f2}) - \mathrm{cov}(r_{s2}, r_{f2})\mathrm{cov}(r_{f1}, r_{f2})}{\mathrm{var}(r_{f1})\mathrm{var}(r_{f2}) - \mathrm{cov}^2(r_{f1}, r_{f2})}$$

$$h_2 = \frac{\mathrm{cov}(r_{s1}, r_{f2})\mathrm{var}(r_{f1}) + \mathrm{cov}(r_{s2}, r_{f2})\mathrm{var}(r_{f1}) - \mathrm{cov}(r_{s1}, r_{f1})\mathrm{cov}(r_{f1}, r_{f2}) - \mathrm{cov}(r_{s2}, r_{f1})\mathrm{cov}(r_{f1}, r_{f2})}{\mathrm{var}(r_{f1})\mathrm{var}(r_{f2}) - \mathrm{cov}^2(r_{f1}, r_{f2})}$$

When using dual instruments to hedge a single risk, the portfolio return is as follows:

$$r_h = -r_s + h_1 r_{f1} + h_2 r_{f2} \tag{2}$$

Then, the hedge ratios under the risk minimization objective are as follows:

$$h_1 = \frac{\mathrm{cov}(r_s, r_{f1})\mathrm{var}(r_{f2}) - \mathrm{cov}(r_s, r_{f2})\mathrm{cov}(r_{f1}, r_{f2})}{\mathrm{var}(r_{f1})\mathrm{var}(r_{f2}) - \mathrm{cov}^2(r_{f1}, r_{f2})}$$

$$h_2 = \frac{\mathrm{cov}(r_s, r_{f2})\mathrm{var}(r_{f1}) - \mathrm{cov}(r_s, r_{f1})\mathrm{cov}(r_{f1}, r_{f2})}{\mathrm{var}(r_{f1})\mathrm{var}(r_{f2}) - \mathrm{cov}^2(r_{f1}, r_{f2})}$$

When using a single instrument to hedge a single risk (single spot position), the return of the portfolio is as follows:

$$\mathrm{r}_h = -r_s + h r_f \tag{3}$$

The hedge ratios under the risk minimization objective are as follows:

$$h = \frac{\mathrm{cov}(r_s, r_f)}{\mathrm{var}(r_f)}$$

This paper takes the XOI (previously the AMEX oil index), MXEF (the MSCI emerging markets index) and SPGSENTR (the S&P GSCI energy index total return) as the cross dual hedging setting (second background). The XOI is a price-weighted index of leading companies that are involved in the exploration, production and development of petroleum. For this kind of index, there is no single direct hedge. Clearly, the XOI faces risks related to the volatility of both the oil and stock markets. Therefore, CL traded on the NYMEX and SP traded on the CME can be used to hedge the risks from the oil and stock markets. Similarly, CL and SP can be chosen as dual hedging instruments to hedge the MXEF. The same holds true for the SPGSENTR. The hedging strategy is the same as equation (2).

4. Econometric models

4.1 DCC

Engle (2002) specifies the DCC model as follows:

$$H_t = D_t R_t D_t \tag{4}$$

$$D_t = \mathrm{diag}\left(h_{1,t}^{1/2}, \ \ldots, \ h_{n,t}^{1/2}\right) \tag{5}$$

$$R_t = \mathrm{diag}\left\{Q_t^{1/2}\right\} Q_t \mathrm{diag}\left\{Q_t^{1/2}\right\} \tag{6}$$

where H_t is the time-varying variance and covariance matrix; D_t is a diagonal volatility matrix and R_t is the correlation matrix.

$$h_{i,t} = \omega_i + \alpha_i \varepsilon_{i,\,t-1}^2 + \beta_i h_{i,\,t-1} \tag{7}$$

$$Q_t = (1 - a - b)\overline{Q} + a z_{t-1} z_{t-1}^{'} + b Q_{t-1} \tag{8}$$

where Q_t is the conditional covariance matrix of the standardized residual; $\overline{Q}$ is the unconditional covariance matrix and a and b are scalar parameters where $a + b < 1$.

4.2 Glosten-Jagannathan-Runkle-GARCH

Glosten *et al.* (1993) propose the Glosten-Jagannathan-Runkle (GJR)-GARCH model to consider the asymmetric volatility effect. This paper adds this to the following specification of the ADCC and copula-ADCC models. The GJR-GARCH (p, q) model can be specified as follows:

$$\sigma_t^2 = \omega + \sum_{i=1}^{p} \beta_i \sigma_{t-i}^2 + \sum_{j=1}^{q} \alpha_j \varepsilon_{t-j}^2 + \sum_{j=1}^{q} \gamma_j \varepsilon_{t-j}^2 I(\varepsilon_{t-j} < 0) \tag{9}$$

where $\omega = 0$, $\beta_i \geq 1$ for $i = 1, \ \ldots, p$, $\alpha_j \geq 0$, and $\alpha_j + \gamma_j \geq 0$ for $j = 1, \ \ldots, q$ and $I(\varepsilon_{t-j} < 0)$ is an indicator function.

The AR(1)-GJR(1,1) (e.g. Pan *et al.*, 2016; Wang *et al.*, 2016) model can be specified as follows:

$$r_{i,\,t} = \mu + \phi\, r_{i,\,t-1} + \varepsilon_{i,\,t} \tag{10}$$

$$h_{i,\,t} = \omega + \alpha \varepsilon_{i,\,t-1}^2 + \gamma \varepsilon_{i,\,t-1}^2 I[\varepsilon_{i,\,t-1} < 0] + \beta h_{i,\,t-1} \tag{11}$$

4.3 ADCC

Cappiello *et al.* (2006) combine the DCC and GJR models and develop the ADCC model:

$$h_{i,\,t} = \omega_i + \alpha_i \varepsilon_{i,\,t-1}^2 + \beta_i h_{i,\,t-1} + d_i \varepsilon_{i,\,t-1}^2 I(\varepsilon_{i,\,t-1} < 0) \tag{12}$$

The variance decreases for negative residuals and negative d. $I(\varepsilon_{i,\,t-1})$ is an indicator function.

The asymmetric effect is usually observed. Q can be shown as follows:

$$Q_t = (\overline{Q} - A'\overline{Q}A - B'\overline{Q}B - G'\overline{Q}^{-}G) + A'z_{t-1}z'_{t-1}A + B'Q_{t-1}B + G'z_t^{-}z_t^{'-}G \tag{13}$$

where G, A and B are the parameter matrix; z_t and z_t^{-} are defined by the series and indicator function and $\overline{Q}$ and $\overline{Q}^{-}$ are the unconditional matrices of z_t and z_t^{-}, respectively.

4.4 Copula-based GARCH

The copula method was first proposed by Sklar (1959). To study the dynamic dependence structure and to capture time-varying dependence, this paper applies a time-varying copula approach (see Fantazzini, 2009; Berger, 2013; Berger and Uddin, 2016), which modifies the classical copula approaches and substitutes the linear correlation coefficient of the Gaussian and T-copula with the DCC coefficient of Engle (2009). The following function shows the Gaussian copula:

$$\begin{aligned} C(u_1, \ldots, u_n) &= \phi_\rho(\phi^{-1}(u_1), \ldots, \phi^{-1}(u_n)), \\ &= \int_{-\infty}^{\phi^{-1}(u_1)} \cdots \int_{-\infty}^{\phi^{-1}(u_n)} \frac{1}{2(\pi)^{n/2}|\rho|^{1/2}} \exp\left(-\frac{1}{2} z^T \rho^{-1} z\right) dz_1, \ldots, dz_n \end{aligned} \tag{14}$$

where ϕ_ρ is the multivariate normal distribution; ρ is the correlation matrix; u_n is the marginal cumulative distribution function and ϕ^{-1} is the inverse of the normal distribution. The T-copula is specified as follows to consider tail dependence and extreme comovement:

$$\begin{aligned} C(u_1, \ldots, u_n) &= t_{\rho,v}(t_v^{-1}(u_1), \ldots, t_v^{-1}(u_n)), \\ &= \int_{-\infty}^{t^{-1}(u_1)} \cdots \int_{-\infty}^{t^{-1}(u_n)} \frac{1}{\Gamma\left(\frac{v}{2}\right)(v\pi)^{n/2}|\rho|^{1/2}} \left(1 + \frac{1}{v} z^T \rho^{-1} z\right)^{-\frac{v+n}{2}} dz_1, \ldots, dz_n \end{aligned} \tag{15}$$

where $t_{\rho,v}$ is the multivariate t distribution; v is the degree of the freedom and t_v^{-1} is the inverse of the t distribution.

After the inclusion of the DCC coefficients, similar to Berger and Uddin (2016), the conditional correlation matrix R_t can be specified as follows:

$$R_t = \mathrm{diag}\left\{Q_t^{1/2}\right\} Q_t \mathrm{diag}\left\{Q_t^{1/2}\right\} \tag{16}$$

$$Q_t = \Omega + \alpha \varepsilon_{t-1} \varepsilon'_{t-1} + \beta Q_{t-1} \tag{17}$$

where $\Omega = (1 - \alpha - \beta) R^{-}$, where α and β are positive, and ε_t is obtained from the GJR (1,1) model.

The DCC copula function with a Gaussian distribution can be shown as follows:

$$C^{\text{gauss}}(u_1, \ldots, u_n) = \phi_{R_t}(\phi^{-1}(u_1), \ldots, \phi^{-1}(u_n)) \tag{18}$$

The DCC-t copula function is as follows:

$$C^t(u_1, \ldots, u_n) = \phi_{R_t,v}(\phi^{-1}(u_1), \ldots, \phi^{-1}(u_n)) \tag{19}$$

First, the parameters $\hat{\theta}_1$ can be determined by the following optimization:

$$\hat{\theta}_1 = \mathrm{ArgMax}_{\theta_1} \sum_{t=1}^{T} \sum_{j}^{n} \ln f_j(u_{jt;\ \theta_1}) \tag{20}$$

Second, $\hat{\theta}_2$ can be determined by the following optimization:

$$\hat{\theta}_2 = \mathrm{ArgMax}_{\theta_2} \sum_{t=1} \ln c(F_1(u_{1t}), F_2(u_{2t}), \ \ldots, F_n(u_{nt}); \theta_2, \hat{\theta}_1) \tag{21}$$

Then, we can estimate the parameters of the copula-based DCC model with a Gaussian and t distribution by the following optimization:

$$\hat{\theta}_2 = \mathrm{ArgMax}_{\theta_2(\alpha,\beta)} \sum_{t=1} \ln c(F_1(u_{1t}), F_2(u_{2t}), \ \ldots, F_n(u_{nt}); \theta_2(\alpha, \beta), \hat{\theta}_2(\alpha, \beta), \hat{\theta}_1) \tag{22}$$

when R_t follows the ADCC model, we can also estimate the parameters of the copula-ADCC-Gauss and copula-ADCC-t models.

4.5 GO-GARCH

The GO-GARCH model of Van der Weide (2002) can be specified as follows:

$$r_t = m_t + \varepsilon_t \text{ and } t = 1, \ \ldots, \ T \tag{23}$$

$\varepsilon_t = Af_t$, where A is constant and invertible. $A = \sum^{1/2} U$, where $\sum^{1/2}$ is the square root of the unconditional covariance matrix, and U is an orthogonal matrix. The independent source factor weights assigned to each series can be shown by the rows of matrix A. The factors can be defined as follows:

$$f_t = H_t^{1/2} z_t \tag{24}$$

Then, the return is as follows:

$$r_t = m_t + AH_t^{1/2} z_t. \tag{25}$$

The conditional covariance matrix of the returns $\sum_t = E[((r_t - m_t)(r_t - m_t)' | F_{t-1}]$ is given as follows:

$$\sum_t = AH_t A' \tag{26}$$

5. Data

In the first setting, this paper uses weekly data on the crude oil spot and futures price and the spot and futures exchange rates of four currencies: the Canadian dollar (CAD), the Japanese yen (JPY), the Swiss franc (CHF) and the British pound sterling (GBP), all relative to the US dollar. We use the futures contract specifying the earliest delivery date. All data are available from Bloomberg.

Our sample period is from January 5, 1990, to December 22, 2017. In this paper, returns are calculated as the difference in the log price between the current and previous price multiplied by 100. Table 1 shows the statistics related to the data. The Jarque-Bera (1980) test is performed for the null hypothesis that there is a Gaussian distribution. LB Q (20) and LB Q^2 (20) are the Ljung-Box (1978) statistics and test for serial correlation up to the 20th order of the return and the squared return series, respectively.

Note that the variance of the oil returns is larger than that of the foreign exchange rate returns. The skewness of the crude oil returns, CAD and GBP is positive, while the skewness of the other variables is negative. From the Jarque–Bera statistics, we find that no data do follow a Gaussian distribution. The Ljung–Box tests show serial correlation up to

Table 1.
Summary statistics for returns

	Spot	Futures	CADUSD	CD	CHFUSD	SF	JPYUSD	JY	GBPUSD	BP
Mean	0.07	0.07	−0.01	−0.01	0.03	0.03	0.02	0.02	−0.01	−0.01
Maximum	25.12	19.84	5.25	5.77	16.67	17.00	14.98	15.09	5.20	4.95
Minimum	−19.23	−18.96	−8.01	−9.32	−11.44	−11.51	−6.03	−5.69	−10.29	−11.74
Median	0.20	0.22	0.04	0.05	0.00	−0.02	−0.06	−0.06	0.05	0.05
Std. dev	4.25	4.10	1.06	1.10	1.60	1.63	1.54	1.57	1.33	1.35
Skewness	−0.15	−0.30	−0.62	−0.79	0.63	0.66	0.90	0.87	−0.74	−0.79
Kurtosis	2.92	2.45	5.77	6.91	9.82	9.73	6.78	6.52	4.29	5.54
JB test	529***	390***	2131***	3069***	5988***	5883***	3002***	2785***	1,259***	2026***
LB Q (20)	81.1***	88.2***	45.8***	55.8***	31.2*	29.8*	27.4	29.0*	30.5*	29.4*
LB Q^2(20)	771.9***	584.0***	786.6***	758.1***	15.0	15.9	105.3***	119.9***	317.0***	208.8***
ARCH(20)	253.3***	187.7***	359.3***	315.7***	13.3	13.9	79.1***	90.4***	137.5***	94.0***

Note(s): Spot: oil spot price. Futures: oil futures price. CADUSD: Canadian dollar. CHFUSD: Swiss franc. JPYUSD: Japanese yen. GBPUSD: Great Britain Sterling Pound. CD, SF, JY and BP refer to the corresponding futures price. * denotes rejection of the null hypothesis at 10% significance level. ** denotes rejection of the null hypothesis at 5% significance level. *** denotes rejection of the null hypothesis at 1% significance level the 20th order, except for the LB Q (20) for JPYUS$ and LB Q^2 (20) for CHFUS$ and Swiss Franc (SF). For the existence of serial correlation, this paper incorporates the AR (1) into the conditional mean equation. In addition, the ARCH test of the autoregressive model (AR) (1) for the return series shows the usefulness of GARCH models, except for the CHF. In summary, for the existence of serial correlation and a fat-tail distribution, this paper adds an AR (1) mean equation with t distribution in the DCC, ADCC, copula-DCC and copula-ADCC models and a normal inverse Gaussian for the GO-GARCH model. The next section contains the robustness results of these specifications.

In the second setting, we take financial institutions as an example. Suppose that they need to hedge the risk of the index, such as the XOI, which does not have a corresponding direct hedging instrument. The XOI is a price-weighted index of leading companies that are involved in the exploration, production and development of petroleum. This index contains the whole price of the component stocks and thus shows the performance of the oil industry. In reality, for this kind of index, there is no single direct hedge. The use of a cross dual hedge has great advantages. Clearly, the XOI faces risks related to the volatility of both the oil and stock markets. Therefore, CL traded on the NYMEX and SP traded on the CME can be used to hedge the risks from the oil and stock markets.

Similarly, the MXEF captures large- and mid-cap representation across 24 EM countries, and it is becoming increasingly important. The literature shows that crude oil prices have affected the development of the global economy, especially in EMs; the relationship between them is becoming closer. Some studies investigate the relationship between oil prices and emerging stock markets (see, for example, Basher *et al.*, 2012). Basher and Sadorsky (2016) use oil, gold, VIX and bonds to single hedge EM stock prices (MXEF) and to analyze which is the best hedging instrument. We also believe that changes in the MXEF are highly related to the volatility of stock markets. Both CL and SP have large trading volumes and good liquidity, and large amounts of research (e.g. Chen and Sutcliffe, 2012; Wang *et al.*, 2015) use them to hedge. Therefore, CL and SP are chosen as dual hedging instruments to hedge the EM index (MXEF) in the next section of this paper, which greatly expands the work of Basher and Sadorsky (2016) in several different ways. The same holds true for the SPGSENTR.

The sample period is from January 18, 1991, to November 10, 2017. Returns are the difference in the log price between the current price and the previous price multiplied by 100. Table 2 shows some preliminary statistics for the data.

	XOI	MXEF	SPGSENTR	CL	SP
Mean	0.120	0.128	−0.002	0.057	0.148
Maximum	15.73	18.54	16.72	24.12	12.26
Minimum	−27.28	−22.56	−27.18	−34.9	−21.82
Median	0.223	0.315	0.152	0.355	0.232
Std. dev	3.015	2.915	4.148	4.949	2.294
Skewness	−0.788	−0.763	−0.688	−0.793	−0.843
Kurtosis	6.757	6.181	3.105	5.186	8.505
JB test	2819.62***	2373.92***	675.95***	1723.15***	4402.35***
LB Q(10)	19.96**	49.65***	20.80**	41.74***	40.01***
LB Q^2(10)	321.58***	714.72***	202.54***	375.12***	352.10***
ARCH(10)	185.00	325.03	159.26	276.33	170.51

Note(s): XOI: oil index. MXEF: emerging markets index. SPGSENTR: GSCI energy index total return CL: oil futures price. SP: S&P500 futures

Table 2. Summary statistics for returns

6. Empirical results

6.1 Hedge ratios

In the first setting, for out-of-sample estimation, we split the whole sample from January 5, 1991, to December 22, 2017, into two subsamples. The first period is from January 5, 1991, to February 27, 2009 (1,000 weekly observations), and is used to estimate the model parameters; it is called the estimation window. The second period is from March 6, 2009, to December 22, 2017 (460 weekly observations), and is used to evaluate out-of-sample hedging performance; it is called the evaluation window. The first 1,000 observations are used to estimate the parameters, and then, we can forecast the first one-step-ahead hedge ratio. The estimation window is rolled forward by dropping the 1st observation and then adding the 1001st observation and estimating one more time and so forth. This is the so-called one-step-ahead rolling estimation.

In the second setting, we split the whole sample from January 18, 1991, to November 10, 2017, into two subsamples. The first period is from January 18, 1991, to March 12, 2010 (1,000 weekly observations). The second period is from March 19, 2010, to November 10, 2017 (400 weekly observations).

6.2 Hedging effectiveness and model confidence set test

Hedging effectiveness (Ederington, 1979) is one of the most popularly used measurements of the performance of different hedging models; it can also be called variance reduction.

$$\mathrm{HE} = \frac{\mathrm{var}_{\mathrm{unhedged}} - \mathrm{var}_{\mathrm{hedged}}}{\mathrm{var}_{\mathrm{unhedged}}}$$

For the single risk hedge with a single instrument, let $h_p = -r_{s,t} + h^* r_{f,t}$ be the hedged portfolio return, where h^* is the hedge ratio estimated at time $t-1$. For the single hedge with the dual instruments, let $h_p = -r_{s,t} + h_1^* r_{f_1,t} + h_2^* r_{f_2,t}$ be the hedged portfolio return. For the dual hedge with dual instruments, let $h_p = -r_{s1,t} - r_{s2,t} + h_1^* r_{f_1,t} + h_2^* r_{f_2,t}$ be the hedged portfolio return. When comparing the hedging performance between the combined use of two single hedges (a single risk hedge with a single instrument) and the dual hedge with a dual instrument, we also let $h_p = -r_{s1,t} - r_{s2,t} + h_1^* r_{f_1,t} + h_2^* r_{f_2,t}$ be the hedged portfolio return of the combined use of the two single hedges. However, in this condition, the two hedge ratios are separately determined by a single hedge, which is different from the dual hedge ratio. This paper also performs the MCS test (Hansen *et al.*, 2011) to observe which model belongs to the superior model set.

Table 3 shows the results of out-of-sample hedging effectiveness and the MCS test in the first setting. In the crude oil & CAD condition, from the longitudinal contrast, the dual hedge of single CAD (CL&CD-CADUS$) does not have better performance than the single hedge of single CAD (CD-CADUS$). The variance reduction (VR) of the single hedge of single crude oil (CL-OIL) is slightly larger than the dual hedge of single crude oil (CL&CD-OIL); however, the difference between them is quite small.

For the crude oil and CHF condition, from the longitudinal contrast, the dual hedge of single CHF (CL&SF-CHFUS$) cannot outperform the single hedge of single CHF (SF-CHFUS$). The VR of the single hedge of single crude oil (CL-OIL) is slightly larger than the dual hedge of single crude oil (CL&SF-OIL). The dual hedge of the dual spot position (CL&SF-OIL&CHFUS$) performs worse than the combination using two single hedges. The results remain the same for the crude oil and JPY and crude oil and GBP conditions.

Table 4 shows the results in the second setting. In the CL&SP-XOI condition, from the longitudinal contrast, all dual hedge VR values are larger than the single hedge VR values. For the CL&SP-MXEF condition, all dual hedges perform better than the single hedges. For the CL&SP–SPGSENTR condition, the dual VR is larger than the single VR for every model.

Table 3. Out-of-sample minimum-variance hedging effectiveness and MCS test

VR	OLS		DCC		ADCC		COPULA-DCC		COPULA-ADCC		GO-GARCH	
	VR	*P*	VR	*P*	VR	*P*	VR	*P*	VR	*P*	VR	*P*
CL-OIL	0.9777	1.0000	0.9769	0.4805	0.9770	0.4424	0.9773	0.5254	0.9773	0.5254	0.9762	0.4424
CD-CADUSD	0.9684	0.2037	0.9684	0.1740	0.9685	0.2037	0.9685	0.2037	0.9687	0.2037	0.9699	1.0000
SINGLE-COMBINATION	0.9807	1.0000	0.9804	0.9535	0.9804	0.9535	0.9805	0.9535	0.9806	0.9535	0.9795	0.9034
CL&CD-OIL&CADUSD	0.9829	0.9670	0.9800	0.6685	0.9801	0.8132	0.9804	0.9670	0.9804	1.0000	0.9798	0.8132
CL&CD-OIL	0.9776	1.0000	0.9764	0.3528	0.9766	0.3528	0.9772	0.7322	0.9772	0.7322	0.9761	0.7322
CL&CD-CADUSD	0.9689	0.5116	0.9687	0.5116	0.9688	0.5116	0.9685	0.3584	0.9688	0.5116	0.9700	1.0000
CL-OIL	0.9777	1.0000	0.9769	0.6086	0.9771	0.6086	0.9773	0.6086	0.9772	0.6086	0.9766	0.6086
SF-CHFUSD	0.9870	0.8011	0.9867	0.3629	0.9869	0.8011	0.9870	0.9153	0.9870	0.9153	0.9871	1.0000
SINGLE-COMBINATION	0.9794	0.9143	0.9791	0.7274	0.9789	0.7274	0.9795	1.0000	0.9794	0.9143	0.9787	0.7274
CL&SF-OIL&CHFUSD	0.9817	0.5671	0.9786	0.1904	0.9788	0.3731	0.9791	0.3731	0.9795	1.0000	0.9783	0.3731
CL&SF-OIL	0.9774	1.0000	0.9765	0.4304	0.9771	0.8443	0.9770	0.7773	0.9773	0.8443	0.9763	0.7773
CL&SF-CHFUSD	0.9870	0.9413	0.9864	0.4381	0.9866	0.7899	0.9870	0.9413	0.9869	0.7899	0.9870	1.0000
CL-OIL	0.9777	1.0000	0.9769	0.5694	0.9771	0.5694	0.9773	0.5694	0.9773	0.5694	0.9766	0.5694
JY-JPYUSD	0.9808	0.0022***	0.9818	1.0000	0.9818	0.9846	0.9809	0.0022***	0.9807	0.0022***	0.9817	0.9846
SINGLE-COMBINATION	0.9765	0.9788	0.9764	0.9668	0.9766	0.9788	0.9766	1.0000	0.9766	0.9788	0.9758	0.9276
CL&JY-OIL&JPYUSD	0.9802	0.8400	0.9762	0.8577	0.9765	1.0000	0.9765	0.9559	0.9764	0.9559	0.9754	0.8400
CL&JY-OIL	0.9774	0.9821	0.9769	0.7196	0.9771	0.9228	0.9774	1.0000	0.9772	0.9228	0.9766	0.7196
CL&JY-JPYUSD	0.9806	0.0841*	0.9810	0.2076	0.9813	1.0000	0.9806	0.0841*	0.9805	0.0841*	0.9812	0.9248
CL-OIL	0.9777	1.0000	0.9769	0.5512	0.9770	0.5512	0.9773	0.5512	0.9773	0.5512	0.9763	0.5512
BP-GBPUSD	0.9854	0.1074	0.9845	0.0455**	0.9842	0.0218**	0.9846	0.0218**	0.9845	0.0218**	0.9855	1.0000
SINGLE-COMBINATION	0.9807	1.0000	0.9800	0.4517	0.9801	0.4108	0.9803	0.4517	0.9802	0.4517	0.9794	0.4108
CL&BP-OIL&GBPUSD	0.9815	1.0000	0.9789	0.0644*	0.9793	0.0644*	0.9797	0.2172	0.9798	0.2172	0.9795	0.2172
CL&BP-OIL	0.9777	1.0000	0.9755	0.0689*	0.9762	0.0689*	0.9766	0.1395	0.9768	0.1395	0.9764	0.1395
CL&BP-GBPUSD	0.9854	0.4786	0.9844	0.0285**	0.9841	0.0153**	0.9846	0.0285**	0.9845	0.0153**	0.9855	1.0000

Note(s): *, ** and *** denote the rejections of the null hypothesis at 10, 5 and 1% different significance levels for the *p*-value (MCS test). OIL: oil spot price. CL: oil futures price. CADUSD: Canadian dollar. CHFUSD: Swiss franc. JPYUSD: Japanese yen. GBPUSD: Great Britain Sterling Pound. CD, SF, JY and BP refer to the corresponding futures price. CL-OIL refers to oil single hedge. CD-CADUSD refers to exchange rate single hedge. CL&CD–OIL&CADUSD refers to 2&2 dual hedge. CL&CD-OIL and CL&CD-CADUSD refer to 2&1 dual hedge. SINGLE-COMBINATION refers to the combination use of two single hedges (single risk hedge with single instrument)

Table 4.
Out-of-sample minimum-variance hedging effectiveness and MCS test

	OLS		DCC		ADCC		COPULA-DCC		COPULA-ADCC		GO-GARCH	
	VR	*P*	VR	*P*	VR	*P*	VR	*P*	VR	*P*	VR	*P*
CL-XOI	0.3595	0.0282**	0.4258	0.9143	0.4272	1	0.4225	0.8454	0.4260	0.9143	0.4128	0.7308
SP-XOI	0.6036	0.0023***	0.6510	0.6473	0.6532	0.6474	0.6555	0.6474	0.6568	1	0.6329	0.3668
CL&SP-XOI	0.7533	0.0493**	0.7689	0.5484	0.7690	0.5484	0.7750	0.7362	0.7759	1	0.7604	0.5311
CL-MXEF	0.1371	0.0019***	0.2084	0.0019***	0.2217	0.5577	0.2177	0.2791	0.2253	1	0.1866	0.0019***
SP-MXEF	0.4701	0.975	0.4618	0.7108	0.4691	0.975	0.4656	0.9644	0.4623	0.7108	0.4719	1
CL&SP-MXEF	0.4980	1	0.4875	0.4185	0.4958	0.9555	0.4853	0.4185	0.4863	0.4185	0.4932	0.9555
CL-SPGSENTR	0.9088	0.4799	0.9093	0.3576	0.9052	0.1316	0.9120	0.4799	0.9112	0.4799	0.9114	0.4799
SP-SPGSENTR	0.1183	0.103	0.1626	0.2913	0.1643	0.2913	0.1764	0.4569	0.1810	1	0.1348	0.2913
CL&SP-SPGSENTR	0.9113	0.3008	0.9105	0.0772*	0.9065	0.0316**	0.9135	0.3316	0.9120	0.1371	0.9141	0.3316

Note(s): XOI: oil index. MXEF: emerging market index. SPGSENTR: GSCI energy index total ret. CL: oil future price. SP: S&P500 future. VR refers to variance reduction. *P* refers to the *p*-value of the MCS test. *,** and*** denote the rejections of the null hypothesis (included in the best model set) at 10, 5 and 1% different significance levels

From the horizontal comparison, for the MCS test in the direct hedging background (the first setting), we can see that the OLS performs best in hedging the single oil risk by using either single or dual hedging instruments, with the *p*-value equals to 1. Besides, GO-GARCH performs best in hedging the single currency risk by using either single or dual hedging instruments. In other conditions, there does not exist one model that can always outperform other ones.

6.3 Hedging performance with the transaction cost

We need to investigate how the TC might affect the different hedging strategies, including dual hedging. Suppose that the TC and the size of the rebalancing required for both hedging instruments have the same linear relationship. The TC can be proxied by the value of futures positions traded each week (see Chen and Sutcliffe, 2012). They take TC/VR as the criterion; the smaller the ratio is, the better the performance. However, when the VR is negative, this criterion is no longer suitable.

Then, we develop a better criterion. Clearly, the ratio $\frac{\text{var}_{\text{unhedged}}}{\text{var}_{\text{hedged}}{}^{*}\text{TC}}$ makes sense. $\text{var}_{\text{unhedged}}$ and $\text{var}_{\text{hedged}}$ show the variance of the unhedged and hedged portfolio, respectively. The larger the ratio is, the better the performance. In addition, $\text{VR} = 1 - \frac{\text{var}_{\text{hedged}}}{\text{var}_{\text{unhedged}}}$. Then, the ratio can be transformed into $\frac{1}{(1-\text{VR})^{*}\text{TC}}$. We name this ratio hedging performance with transaction costs (HPTC). Then, we can compare the performance of the single and dual hedges.

Table 5 shows the HPTC for six different models in the first setting. TC represents transaction costs. VR represents variance reduction. The larger the HPTC is, the better the performance.

For all currencies, after taking the transaction costs into account, from the longitudinal contrast, the dual hedge of the single exchange rate risk cannot always outperform the single hedge of the single exchange rate risk. This suggests that when the airline companies hedge the exchange rate risk, they do not have to add CL as an additional instrument and use the dual hedge strategy. A dual hedge may not be a worthwhile expense to achieve better performance in this dual hedge of a single exchange rate risk condition. The HPTC of the single hedge of single crude oil (CL-OIL) is larger than that of the dual hedge of single crude oil. This suggests that when the airline companies hedge the single crude oil risk, they do not have to use the dual instrument. In addition, the dual instrument hedge of the dual spot position performs worse than the combination using the two single hedges. A dual hedge is not a worthwhile expense to achieve better performance in this dual instrument hedge of the dual spot position condition. In summary, in this direct hedging setting, the dual hedge cannot outperform the single hedge.

Table 6 shows the HPTC for six different models in the second setting. In the CL&SP-XOI condition, after taking the TC into account, all the dual hedges still show better performance than the single hedge. The results of the HPTC coincide with those of the VR. A dual hedge is a worthwhile expense for traders to obtain a substantial risk reduction in this context. For the CL&SP-MXEF condition, the performance of the dual hedge becomes slightly inferior to that of the single hedge. In the CL&SP-SPGSENTR condition, after taking the TC into account, all the dual hedges still show better performance than the single hedges. In summary, the dual hedge does not perform worse than the single hedge.

6.4 Robustness

In the first setting, in the previous sections, the hedge ratio is estimated using the rolling window method with a fixed size of 1,000 and including an AR (1) mean equation with Student's *t* distribution for the DCC, ADCC, copula-DCC, copula-ADCC models and a normal inverse Gaussian distribution for the last GO-GARCH model. As a robustness check, this paper makes several adjustments and compares the corresponding hedging performance and performs the MCS test.

Table 5.
Hedging performance with transaction cost

VR	OLS TC	OLS VR	OLS HPTC	DCC TC	DCC VR	DCC HPTC	ADCC TC	ADCC VR	ADCC HPTC	COPULA-DCC TC	COPULA-DCC VR	COPULA-DCC HPTC	COPULA-ADCC TC	COPULA-ADCC VR	COPULA-ADCC HPTC	GO-GARCH TC	GO-GARCH VR	GO-GARCH HPTC
CL-OIL	2.81	0.9777	15.97	2.77	0.9769	15.65	2.78	0.9770	15.64	2.77	0.9773	15.93	2.77	0.9773	15.86	2.76	0.9762	15.21
CD-CADUSD	0.89	0.9684	35.53	0.92	0.9684	34.32	0.93	0.9685	34.25	0.92	0.9685	34.67	0.92	0.9687	34.76	0.91	0.9699	36.40
SINGLE-COMBINATION	3.14	0.9807	16.49	3.12	0.9804	16.33	3.13	0.9804	16.35	3.11	0.9805	16.46	3.12	0.9806	16.47	3.10	0.9795	15.75
CL&CD-OIL&CADUSD	3.14	0.9829	18.59	3.13	0.9800	15.96	3.14	0.9801	16.03	3.13	0.9804	16.32	3.14	0.9804	16.29	3.13	0.9798	15.81
CL&CD-OIL	2.80	0.9776	15.89	2.77	0.9764	15.32	2.77	0.9766	15.42	2.77	0.9772	15.84	2.78	0.9772	15.78	2.76	0.9761	15.15
CL&CD-CADUSD	0.89	0.9689	35.94	0.93	0.9687	34.49	0.93	0.9688	34.55	0.92	0.9685	34.63	0.92	0.9688	34.83	0.92	0.9700	36.37
CL-OIL	2.81	0.9777	15.97	2.76	0.9769	15.69	2.79	0.9771	15.70	2.77	0.9773	15.94	2.78	0.9772	15.80	2.75	0.9766	15.56
SF-CHFUSD	1.13	0.9870	67.98	1.14	0.9867	65.86	1.14	0.9869	66.92	1.13	0.9870	68.35	1.14	0.9870	67.67	1.14	0.9871	68.15
SINGLE-COMBINATION	3.13	0.9794	15.51	3.10	0.9791	15.44	3.12	0.9789	15.21	3.09	0.9795	15.77	3.11	0.9794	15.64	3.08	0.9787	15.19
CL&SF-OIL&CHFUSD	3.11	0.9817	17.60	3.08	0.9786	15.20	3.11	0.9788	15.19	3.08	0.9791	15.55	3.10	0.9795	15.77	3.07	0.9783	15.03
CL&SF-OIL	2.81	0.9774	15.76	2.76	0.9765	15.46	2.79	0.9771	15.67	2.76	0.9770	15.77	2.77	0.9773	15.86	2.75	0.9763	15.32
CL&SF-CHFUSD	1.13	0.9870	68.06	1.14	0.9864	64.75	1.14	0.9866	65.41	1.13	0.9870	68.08	1.14	0.9869	66.78	1.14	0.9870	67.96
CL-OIL	2.81	0.9777	15.97	2.78	0.9769	15.59	2.79	0.9771	15.62	2.77	0.9773	15.93	2.79	0.9773	15.80	2.74	0.9766	15.58
JY-JPYUSD	1.05	0.9808	49.59	1.07	0.9818	51.14	1.07	0.9818	51.20	1.06	0.9809	49.55	1.05	0.9807	49.21	1.07	0.9817	51.27
SINGLE-COMBINATION	2.97	0.9765	14.35	2.95	0.9764	14.37	2.96	0.9766	14.41	2.94	0.9766	14.58	2.95	0.9766	14.46	2.92	0.9758	14.15
CL&JY-OIL&JPYUSD	2.94	0.9802	17.20	2.94	0.9762	14.27	2.96	0.9765	14.39	2.92	0.9765	14.56	2.95	0.9764	14.39	2.89	0.9754	14.07
CL&JY-OIL	2.81	0.9774	15.77	2.78	0.9769	15.59	2.79	0.9771	15.65	2.76	0.9774	16.03	2.78	0.9772	15.77	2.75	0.9766	15.54
CL&JY-JPYUSD	1.05	0.9806	48.98	1.07	0.9810	49.08	1.07	0.9813	49.83	1.06	0.9806	48.82	1.05	0.9805	48.67	1.07	0.9812	49.96
CL-OIL	2.81	0.9777	15.97	2.78	0.9769	15.57	2.78	0.9770	15.64	2.77	0.9773	15.90	2.78	0.9773	15.82	2.75	0.9763	15.39
BP-GBPUSD	0.95	0.9854	72.22	0.95	0.9845	67.89	0.95	0.9842	66.59	0.95	0.9846	68.51	0.95	0.9845	68.08	0.95	0.9855	72.84
SINGLE-COMBINATION	3.10	0.9807	16.73	3.07	0.9800	16.31	3.08	0.9801	16.30	3.06	0.9803	16.57	3.07	0.9802	16.48	3.04	0.9794	15.95
CL&BP-OIL&GBPUSD	3.10	0.9815	17.45	3.07	0.9789	15.44	3.08	0.9793	15.71	3.06	0.9797	16.09	3.08	0.9798	16.13	3.05	0.9795	16.02
CL&BP-OIL	2.80	0.9777	15.97	2.77	0.9755	14.70	2.79	0.9762	15.11	2.77	0.9766	15.41	2.78	0.9768	15.48	2.75	0.9764	15.41
CL&BP-GBPUSD	0.95	0.9854	72.52	0.95	0.9844	67.21	0.95	0.9841	65.97	0.95	0.9846	68.32	0.95	0.9845	67.66	0.95	0.9855	72.87

Note(s): TC refers to transaction costs. VR refers to variance reduction. HPTC refers to hedging performance with transaction cost. The larger of the HPTC, the better of the performance.CL-OIL refers to oil single hedge. CD-CADUSD refers to exchange rate single hedge. CL&CD-OIL&CADUSD refers to 2&2 dual hedge. CL&CD-OIL and CL&CD-CADUSD refer to 2&1 dual hedge. SINGLE-COMBINATION refers to the combination use of two single hedges (single risk hedge with single instrument)

	TC	VR	HPTC	TC	VR	HPTC	TC	VR	HPTC
		OLS			DCC			ADCC	
CL-XOI	1.02	0.36	1.53	1.25	0.43	1.39	1.26	0.43	1.38
SP-XOI	1.30	0.60	1.95	1.56	0.65	1.83	1.56	0.65	1.85
CL&SP-XOI	1.58	0.75	2.56	1.78	0.77	2.43	1.78	0.77	2.43
CL-MXEF	0.57	0.14	2.02	0.71	0.21	1.79	0.72	0.22	1.79
SP-MXEF	1.21	0.47	1.56	1.22	0.46	1.52	1.24	0.47	1.52
CL&SP-MXEF	1.28	0.50	1.55	1.29	0.49	1.51	1.31	0.50	1.52
CL-SPGSENTR	2.35	0.91	4.68	2.45	0.91	4.50	2.43	0.91	4.34
SP-SPGSENTR	0.72	0.12	1.57	0.97	0.16	1.24	1.06	0.16	1.13
CL&SP-SPGSENTR	2.35	0.91	4.80	2.45	0.91	4.56	2.43	0.91	4.41
		COPULA-DCC			COPULA-ADCC			GO-GARCH	
CL-XOI	1.20	0.42	1.45	1.20	0.43	1.46	1.01	0.41	1.69
SP-XOI	1.56	0.66	1.86	1.56	0.66	1.87	1.41	0.63	1.93
CL&SP-XOI	1.79	0.77	2.48	1.79	0.78	2.50	1.64	0.76	2.54
CL-MXEF	0.73	0.22	1.74	0.77	0.23	1.68	0.49	0.19	2.49
SP-MXEF	1.24	0.47	1.51	1.28	0.46	1.45	1.14	0.47	1.66
CL&SP-MXEF	1.31	0.49	1.49	1.33	0.49	1.47	1.24	0.49	1.59
CL-SPGSENTR	2.49	0.91	4.57	2.47	0.91	4.56	2.51	0.91	4.51
SP-SPGSENTR	0.99	0.18	1.22	1.10	0.18	1.11	0.67	0.13	1.72
CL&SP-SPGSENTR	2.48	0.91	4.65	2.46	0.91	4.61	2.50	0.91	4.65

Note(s): TC refers to transaction costs. VR refers to variance reduction. HPTC refers to hedging Performance with transaction cost. The larger of the HPTC, the better of the performance
XOI: oil index. MXEF: emerging markets index. SPGSENTR: GSCI energy index total ret
CL: oil futures price. SP: S&P500 futures

Table 6.
Hedging performance with transaction cost

This paper expands the evaluation window size from 460 to 730 and then reexamines the hedging performance. For the longitudinal contrast of the VR, the results are all the same as those for the 460 out-of-sample specification. We also calculate the hedging performance with the transaction cost. The results are also robust to different hedging performance criteria (VR and HPTC). The dual hedge cannot outperform the single hedge. Besides, we also estimate the hedge ratio under a normal distribution and without AR (1) in the mean equation. The results clearly do not change under different specifications. The results are also robust.

In the second setting, the robustness check has been performed, and result does not change.

All these robustness checks need a great amount of work, and the result tables occupy a huge space. Due to space limitations, we do not show all these robustness result tables here.

7. Conclusion

The existing literature that deals with oil prices and foreign exchange rates mostly concentrate on their relationship and comovements, while the dual hedge of integrated risks in this setting remains underresearched. Besides, the existing literature that deals with dual hedge gets its conclusions only based on a single specific background and lack deeper investigation. In this paper, we not only first consider the dual hedge of integrated risks in this oil prices and foreign exchange rates setting but also make a novel comparison between the dual and single hedging strategy from a direct and cross hedging perspective.

This paper studies this topic under two different setting. The first case is the direct dual hedging setting. The second case is the cross dual hedging setting. In total, six different models are used to estimate hedge ratios under the minimum-variance objective. To obtain a more comprehensive and robust result, more advanced models such as the GO-GARCH, copula-DCC and copula-ADCC models are employed; they may better describe the risk correlation, dependence structure and high-dimensional systems. Besides the VR, we also develop a new criterion HPTC to analyze and compare hedging performance. OLS performs best in hedging the single crude oil risk, and GO-GARCH performs best in hedging the single currency risk by using either single or dual hedging instruments in the direct hedging background.

The results show that in the direct hedging setting, a dual hedge cannot outperform a single hedge. However, in the cross dual hedging setting, the dual hedge outperforms the single hedge most of the time. The findings are robust to different sample periods, estimation windows, distribution assumptions and performance criteria. We provide a reasonable explanation for this revealing conclusion. A dual hedge brings different levels of advantages and disadvantages in the two different settings. Compared to a single hedge, the advantage of a dual hedge is that the use of dual instruments can raise its correlation with the underlying asset. That is, a dual hedge can increase hedging performance. However, the disadvantage is that the use of dual instruments may increase the transaction cost, which, in turn, will reduce hedging performance. In the first case (the direct hedging setting), the advantage of the increased explanatory capability is offset by the disadvantage of the increased cost because the explanatory capability of the original single direct hedge is already strong. However, in the second case (the cross dual hedging setting), the hedging instrument is not highly correlated with the underlying asset, and the hedging performance of the single hedge is not particularly good. Thus, the use of dual hedging instruments can better describe their correlation and increase hedging performance. Additionally, this can easily offset the disadvantage of the transaction cost and increase overall hedging performance. Therefore, in the second case (the cross dual hedging setting), the dual hedge outperforms the single hedge most of the time.

The results of this paper offer some suggestions. In the direct hedging setting, a dual hedge may not be a worthwhile expense to achieve better performance. For situations in which there does not exist a direct hedging instrument for a spot position and the spot asset is exposed to several correlated risks, it is beneficial to take advantage of the dual hedge, which can be more reasonable and advantageous.

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