Investigating the risk-return trade-off for crude oil futures using high-frequency data

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HIGHLIGHTS

- The contemporaneous relation between risk and return of crude oil futures is significantly negative.
- The contemporaneous negative relation between downside risk and return is stronger than volatility/jump risk.
- The intertemporal volatility/jump risk-return relationship is insignificant.
- There is weak negative correlation between downside risk and excepted return in the crude oil futures market.
- There is not the risk–return trade-off in the crude oil futures market.

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ABSTRACT

This paper comprehensively examines the existence and significance of a contemporaneous/intertemporal risk-return trade-off for crude oil futures using high-frequency transaction data. The results reveal that the contemporaneous relation between risk (volatility risk, downside risk or jump risk) and return in the crude oil futures market is negative and statistically significant and that the contemporaneous negative relation between downside risk and return is stronger than the two others. However, the intertemporal volatility/jump risk-return relationship is insignificant, and there is weak negative correlation between downside risk and expected return in the crude oil futures market. These findings can be explained by the asymmetric effect of risk on returns. The findings are robust across different samples and different measures of volatility, downside and jump risks. Thus, there is no risk-return trade-off in the crude oil futures market.

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1. Introduction

The crude oil market plays an important role in the economic system [1]. Crude oil is one of the most important energy sources for a nation's economic development [2–4]. Thus, analyzing crude oil futures has attracted considerable attention from academics, governments and investors.

Among the various research topics on crude oil futures, estimating the risk-return relationship in the crude oil futures market is of special interest for energy researchers. Notably, the empirical evi-

dence is mixed. Some researchers find that there is a risk-return trade-off for crude oil futures (see, e.g., [5–7]). However, some studies support the contention that the relation between risk and return in the crude oil futures market is negative (see, e.g., [8–11]).

Thus, the research results are inconsistent, and accurately estimating the risk-return relationship in the crude oil futures market is a challenging task. In this paper, we comprehensively analyze the relationship between contemporaneous/intertemporal risk and return in the crude oil futures market. Compared with the existing literature, our study offers the following advantages and contributions. First, existing studies focus mainly on the correlation between volatility risk and return of crude oil futures (see, e.g., [10,11]). However, we not only estimate the volatility risk-return relationship but also investigate the downside/jump

risk-return relationship in the crude oil futures market. Second, some studies show that the contemporaneous risk-return relationship and intertemporal risk-return relationship is different (see, e.g., [5,8]). Thus, our analysis is more comprehensive and examines both the contemporaneous risk-return relationship and intertemporal risk-return relationship in the crude oil futures market. Third, the overwhelming majority of studies use low-frequency data to measure risk when investigating the risk-return trade-off for crude oil futures (see, e.g., [7,10]). We use high-frequency transaction data to measure the volatility, downside and jump risks of crude oil futures. The high-frequency transaction data contain far more information than the low-frequency transaction data, which more accurately measure the risks (see [12–14]). Thus, our empirical results are more reliable than the results based on low-frequency transaction data. Finally, we find that the failure of both contemporaneous and intertemporal risk-return tradeoffs in the crude oil futures market and the asymmetric effect of risk on returns are important reasons for the lack of evidence of contemporaneous and intertemporal risk-return tradeoffs. Our findings can be utilized to enhance risk management and portfolio diversification, and help investors to make better choices under uncertainty in the crude oil futures market.

The remainder of this paper is organized as follows. The next section offers a literature review that addresses studies on the risk-return relationship in energy markets, in particular the oil market. In Section 3, we measure the volatility, downside and jump risks. Section 4 describes the data. In Section 5, we estimate the relationship between contemporaneous risk and return for crude oil futures using high-frequency transaction data. Section 6 examines the existence and significance of an intertemporal risk-return trade-off in the crude oil futures market through high-frequency data. Section 7 concludes.

2. Literature review

The risk-return trade-off in energy markets is a hot topic. In recent years, many researchers have paid close attention to the relation between risk and return in the energy project investment and the energy futures markets.

Many studies analyze the risk and return relationship in energy project investment, for example, carbon capture and storage (CCS) technologies in power generation plant investment [15], wind energy investment [16], coal-fired electricity investment [17], and community-based photovoltaic investment [18]. Generally, there is a risk-return trade-off in energy project investment.

However, the findings do not appear to be consistent, in particular in the crude oil futures market. Some studies show that the relation between the risk and return of crude oil futures is positive. Kolos and Ronn [5] found that the market price of risk estimates in US markets (Pennsylvania–New Jersey–Maryland forwards, Cinergy, Gas and Oil) is positive, but most are not statistically significant. In the European Energy Exchange market, they found that the commodity market price of risk is significantly positive. Cotter and Hanly [6] estimated a time-varying measure of risk aversion by applying a GARCH-M model and found that the coefficient of relative risk aversion was positive, indicating that the relationship between volatility and expected return of NYMEX New York Harbor (HU) Unleaded Gasoline was positive. Cifarelli and Paladino [7] used a univariate GARCH(1,1)-M model to estimate the relation between volatility risk and return. The evidence suggested that there is a positive feedback trading and positive volatility risk and return relationship in the oil market.

However, some studies found that the risk and return relationship in the crude oil futures market was negative. Following

Cifarelli and Paladino [7], Li et al. [8] found an intertemporal negative relation between the return on the price of oil futures and volatility components. In addition, Miffre et al. [19] indicated that there is a negative relationship between idiosyncratic volatility risk and expected returns in commodity futures markets (including the crude oil market) under traditional benchmarks. Kristoufek [9] also found that the correlation between returns and the volatility risk of both Brent and WTI crude oils is negative. Chatrath et al. [10] showed that the relation between crude oil futures returns and implied volatility risk is negative. Chiarella et al. [11] used a continuous time stochastic volatility model to study the relationship between return and volatility risk in commodity futures markets. Their empirical results indicated a negative relation in the crude oil futures market, in particular during periods of high volatility risk driven mainly by market-wide shocks.

In summary, it must be noted that the literature provides a number of good references for understanding the relationship between risk and return in the crude oil futures market. However, it is necessary to further analyze certain issues, such as the downside/jump risk-return relationship, the contemporaneous and intertemporal risk-return relationship, and the relationship between risk and return using high-frequency transaction data. In this paper, we study the above mentioned issues and investigate the risk-return trade-off in the crude oil futures market based on high-frequency data.

3. Alternative risk measures

3.1. Volatility risk

Volatility risk denotes the fluctuation in financial asset prices and is used to measure uncertainty in return on assets and reflect the risk level of financial assets. Volatility risk in financial markets cannot be observed, and thus a method is required to measure it (see, e.g., [20,21,12]). There are many methods to measure volatility risk, such as GARCH-class models (see, e.g., [20,22–26]) and SV-class models (see, e.g., [21,27,28]), among others (see, e.g., [29]). However, GARCH-type and SV-type models do not adequately describe whole-day volatility information as they use low-frequency data to measure volatility. In the last few decades, computers have greatly reduced the cost of recording and storing high-frequency data, which are now important in the study of volatility in financial markets. Andersen and Bollerslev [12] first used high-frequency data to propose a new method of measuring volatility (i.e., realized volatility, RV). Compared with GARCH-type and SV-type models, realized volatility has two main advantages. On the one hand, it is based on model-free measures and can be calculated directly. On the other hand, realized volatility is computed using high-frequency transaction data, which contain more fluctuation information. Thus, it is a more accurate proxy variable for volatility risk in financial markets. Many studies (see, e.g., [30,31,32]) have therefore used realized volatility to measure volatility risk. Therefore, we choose realized volatility to measure the volatility risk of crude oil futures.

Daily realized volatility can be written as

$$RV_{t'}^{d0} = \sum_{i=1}^{N} r_{t',i}^2 \tag{1}$$

where $r_{t',i}$ is the ith return ($i = 1, \ldots, N$) in day t', i.e., $r_{t',i} = 100(\ln P_{t',i} - \ln P_{t',i-1})$. $P_{t',i}$ is the ith closing price in day t'.

However, Eq. (1) does not consider the overnight return variance, and it is not the consistency estimation of integrated volatility [33]. Therefore, following Andersen et al. [34], Gong et al. [35] and Huang et al. [36], we obtain the new daily realized volatility.