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Dependence and risk assessment for oil prices and exchange rate portfolios: A wavelet based approach

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HIGHLIGHTS

- Financial models (EVT, copulas, DCC-EGARCH) are combined with wavelet transforms.
- These wavelet-based models help accommodate the complex structure of financial data.
- They are then applied to both denoised and original data of oil and exchange rates.
- We find that wavelet transforms enable the detection of extreme events in return data.
- The proposed models help improve the accuracy of portfolio's market risk.

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ABSTRACT

In this article, we propose a wavelet-based approach to accommodate the stylized facts and complex structure of financial data, caused by frequent and abrupt changes of markets and noises. Specifically, we show how the combination of both continuous and discrete wavelet transforms with traditional financial models helps improve portfolio's market risk assessment. In the empirical stage, three wavelet-based models (wavelet-EGARCH with dynamic conditional correlations, wavelet-copula, and wavelet-extreme value) are considered and applied to crude oil price and US dollar exchange rate data. Our findings show that the wavelet-based approach provides an effective and powerful tool for detecting extreme moments and improving the accuracy of VaR and Expected Shortfall estimates of oil–exchange rate portfolios after noise is removed from the original data.

1. Introduction

The analysis of comovement between financial time series is an important issue in financial economics and it remains an important challenge for both financial market agents and academic researchers. The first and foremost reason is that the historical data of financial time series are the outcome of a complex economic process that include, among others, continuing structural changes, policy shifts, real and financial shocks, crises, political tensions, and wars [1]. The combined effects of these events are the root of stylized (and well-known) distributional characteristics of financial time series such as asymmetry, nonlinearity, heavy-tailness, and extreme values. Au et al. [2] note that disregarding these irregularities during the statistical modeling tasks may lead to misleading conclusions. Besides, Haven et al. [3], and Sun and Meinl [4] stress that most data generating processes convey noises that are caused by the complex structure of irregularities and roughness.

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They thus suggest the use of wavelet analysis to denoise the data and to address the manifold irregularity along with both time and different measuring scales. For instance, Haven et al. [3] focus on intraday option prices and show that denoising with the wavelet method is not only effective but necessary. Wavelet analysis is also particularly appropriate in economic and financial modeling as many economic processes are driven by economic agents that have different term objectives [5].

In the spirit of the above, the main objective of this article is to show the effectiveness and need of combining wavelet analysis with traditional models in analyzing the comovement of financial time series and in improving the accuracy of market risk estimations. Our empirical exercise, which takes a multi-model perspective into account, shows that not only we can detect extreme movements in the time-paths of crude oil and exchange rate returns, but also generates more accurate estimates of Value-at-Risk (VaR) and Expected Shortfall (ES) after the data are denoised through the multi-scaling application of the wavelet method.

More specifically, we contribute to the existing literature in several important aspects. We *first* employ the appropriate wavelet method to remove noise from raw data and to investigate the long-term properties (denoised or smoothed parts) of the relationships between oil prices and exchange rates. Our main motivation arises from the fact that crude oil and exchange rate returns may contain significant noise components, owing particularly to changing market conditions and heterogeneous market agents with different term objectives. We indeed consider three wavelet-based models (the DCC-EGARCH model, copula-GARCH, and EVT), while most recent studies usually focus on only one of them. The DCC-EGARCH is a flexible model that captures time-varying conditional correlations and asymmetric volatility effects of financial time series. The copula-GARCH technique offers the possibility to model the joint (nonlinear) dynamics of financial variables as well as their extreme dependence structure. For its part, the extreme value approach is suitable for dealing with extreme financial events and the quantification of extreme market risk. Altogether, these models allow us to capture some of the most important stylized facts of financial returns including volatility persistence, volatility asymmetry, heavy tails, skewed distributional behavior, and asymmetric tail dependence. Their relevance and usefulness in modeling the dynamics of financial variables have been recently demonstrated [6–8], except for the wavelet-DCC-EGARCH model which is implemented for the first time in our study. Moreover, we attempt to select the best fitting distribution for returns on crude oil and exchange rates as well as those on constructed portfolios in order to guarantee the robustness of the empirical results. While existing works usually consider the normal distribution or several alternative distributions, we conduct a broad investigation of 61 distributions.

Second, the use of wavelets in our study goes beyond its conventional role of noise removal. In a preliminary step, we employ continuous wavelet transform (CWT) to detect the potential of extreme movements that may exist in the underlying dynamics of the data, which particularly motivate the application of copula-GARCH and ETV approaches. Two types of discrete wavelet transform (DWT) are then used to extract the denoised parts of oil and exchange rate returns. Their performance in encircling data variability is compared in terms of the contribution of the denoised parts' variance to the total variability of the original series.

Finally, we show how the estimated results from the considered models can be used for better estimating the VaR of an equally weighted portfolio of crude oil and exchange rates. The VaR is particularly attractive because of its conceptual simplicity and it has been established by the Basel Committee on Banking Supervision (1996) as the official tool for evaluating, monitoring and managing market risk on a specific portfolio of assets. Under the Basel II Accord, regulated financial institutions are allowed to use the VaR estimates from their internal models to determine the daily capital charges that need to be set aside to cover unfavorable market movements. While our article does not directly deal with banks' asset portfolios, banks can benefit from the empirical insights to improve the accuracy of their VaR models. In addition, we propose a more efficient way to accurately determine the VaR by allowing it to depend entirely on the best empirical distribution of portfolio returns. The Expected Shortfall (ES) is also considered to ensure the robustness of the results.

A number of recent empirical studies have investigated the interactive links between crude oil prices and foreign exchange rates. Aloui et al. [9] briefly survey this literature and show that empirical results can be broadly categorized into two groups: (i) positive link between the oil prices and nominal and real US dollar exchange rates (e.g., Refs. [10–12]); and (ii) negative oil–dollar link (e.g., Refs. [13–15,9]). Although the empirical evidence is sometimes conflicting with regard to the sign of oil price effects on exchange rates as well as to the causality direction, all these studies show significant return and volatility relationships between the two variables. This literature is still growing given that crude oil serves as a strategic energy resource for national industrial production and the economic growth of all countries in the world, and that the most commonly used currency for international crude oil trading is the US dollar. Recent research is also motivated by the fact that crude oil prices have experienced unusual fluctuations since 2001 and have become more volatile than they were over the period from World War II to the early 1970s [16,17]. Therefore, participants in the crude oil market, particularly producers, consumers, and traders, are not only concerned by variations in the oil prices, but also by the comovement between oil prices and US dollar exchange rates. Inversely, investors in the US dollar market may have interest to add the crude oil asset into their currency portfolios to hedge against unfavorable movements in the exchange rates. This context emphasizes the need of addressing the joint dynamics between oil prices and US dollar exchange rates as well as risk management issues of portfolios involving both crude oil and currencies. The oil price–exchange rate nexus is also of great interest for economic policy designs, particularly in countries that are sensitive to oil price changes and practice floating exchange rate regimes.

Applying our wavelet-based models and their standard versions to monthly closing price data for the West Texas Intermediate (WTI) crude oil benchmark and the US dollar exchange rates of five major currencies (Canadian Dollar, Great British Pound, Swiss Franc, Japanese Yen, and Norwegian Krone), we find that all considered models enable to capture the features of underlying data, but those using denoised series from wavelet analysis outperform those using original series