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Cross dynamics of oil-stock interactions: A redundant wavelet analysis

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ABSTRACT

The main aim of the present paper is to explore how the interactions between crude oil (CO) price changes and stock returns of five developed countries namely U.S.A, Canada, Germany, Japan and U.K., evolve simultaneously over time and frequency, in light of the conflicting evidence provided by much of recent studies on the sign and the direction of this relationship. To this end, we apply a more efficient wavelet tool, namely Haar à trous wavelet transform that helps circumvent the problems of the standard regression techniques and proves its effectiveness in encircling the real data features. In order to provide more credible conclusions, the wavelet variance, correlation and cross-correlation are implemented. In general, we extend the existing empirical works by providing more generalized and convincing results inherent to the stock-oil markets interactions which are usually reputed to be complicated. First, we find evidence that the wavelet variances of all the variables decrease with increasing scales. Second, from the analysis of the wavelet correlation, changes in CO and almost all the stock prices do not move together up to the intermediate scale, but since they abruptly shift their direction in unison. Third, results for the wavelet CCF at scales 2, 3 and/or 4 generally illustrate no transmission mechanism between CO and the stock market returns although we provide support for massive CO variations at these scales. In contrast, the CO-equity market relationships at higher scales become interconnected in a negative unidirectional pattern running from CO to stock market returns for only two oil importing countries but also Canada. For oil exporting countries, we have seen that while highly transient (scale 1) positive/negative causalities flowing from TSX stock market to CO changes are detected, highly persistent (scale 6) positive causality running from FTSE to the CO changes are rather found. Finally, the implications of the study's results vary depending on the oil – stock market linkages' sensitivity to the degree of improvement in energy efficiency of a given country, the degree of oil shock persistence, and to whether a country is oil importer or exporter (among other suggested factors).

1. Introduction

While a growing number of empirical studies tend to explore the impact of oil shocks on economic activity, the enquiry concerning its effect on the stock market returns has received somewhat scant attention from economists [1]. Even though some evidence exists for this relationship, they provide regrettably mixed results. This lack of consensus in the research literature may be partly due to the inherent deficiencies in the empirical approaches they adopt (among the used set of techniques we cite; simple linear regression, standard GARCH specifications, Granger causality test, Cheung and Ng test,…) that we will discuss in more details in the following section. Thus, it becomes essential to overcome these difficulties through the use of more advanced non-linear techniques.

At this stage an interesting question can arise when exploring this enormously complex oil – stock markets nexus: With the aim of surmounting the gaps of traditional approaches without resorting to very complicated approaches or extending a variety of models, what is the most productive technique that can be used to get unbiased, meaningful and more reliable results?

The apparently complex behavior of financial time series has long been attributed to the presence of non-linear stochastic or even chaotic dependences (or a combination of both). Therefore it is difficult to establish an effective prediction model based on the general time series analysis. In the last decades, the fractional Brownian motions (among other theories) (fBm),[1] which are

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[1] This fBm process also called a "fractal Brownian motion" has the important self-similarity (unifractality) property which implies the presence of long range space-time correlations. While the unifractal (uniscaling) process has a linear scaling function, the multifractal process (a generalized scaling form that involves both extreme variations and long-memory [12]) is characterized by the non-linearity of functions.

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sometimes referred to as $1/f$ noise, have widely been considered as empirically plausible models for financial time series [2]. These theoretical concepts have led to the emergence of a new statistical property in financial time series[2]: the scaling.

Indeed, the wavelet transforms and more particularly the discrete wavelet transforms (DWT) have become increasingly popular tools for detecting the now well-known phenomena of self-similarity (scaling) in financial time series. Among these time series, we evoke for example the crude oil (CO) prices known as the very complex non-linear time series [3,4], stock prices [5] and exchange rates [6,7].

Despite the advantages of DWT, it remains little known and rarely used as a tool for analyzing the dynamic relationship between macroeconomic variables, but it is starting to enter the widespread mainstream usage. In recent years, the non-orthogonal maximal overlap discrete wavelet transform (MODWT), also known as stationary or shift invariant wavelet transform has been applied by most, if not all, research studies aimed to explore the dynamic relationship between macroeconomic variables (some of these studies include [8–11]).

In this paper, we try to investigate the relationship between oil price changes and stock market returns for five developed countries namely USA, Canada, Germany, Japan and United Kingdom using a novel discrete wavelet technique. In order to take into account the CO as well as equity data characteristics in an adequate way, we employ the wavelet technique which appears to be the most promising in capturing more efficiently the main features and in reducing noise contents in signals offering thus more amenable interaction analysis.

More specifically, we are interested in an alternative wavelet method, namely Haar à trous Wavelet (HTW) approach, to use which is introduced by Murtagh et al. [13]. One of the reasons behind selecting this particular method is its ease in dealing with boundary conditions (without sub-sampling the filtered outputs), necessary to characterize and monitor, in a more convenient way the dynamic relationship between CO shocks and stock market returns for five developed countries.

Bearing in mind some of the traditional DWT's limitations (see section 3.1), Murtagh et al. [13] pointed out two basic considerations that come into play in using the HTW instead of the traditional DWT techniques which are specified as follows: (i) the redundancy (non-decimation or translation-invariance) of the à trous wavelet (*with holes*) that ensures zero phase filtering at each level since the down-sampling and up-sampling stages are removed. But it remains symmetric function which is problematic for handling boundary values. (ii) Preservation of the asymmetric nature of the time-varying signal, which leads to the use of the Haar wavelet function. In other words, events at time t in the original series are associated with the corresponding coefficients at time t (Detail/smooth coefficients). However, the Haar wavelet is a decimated one. In short, the solution proposed by these authors is to use the two wavelet techniques (à Trous and Haar) together so as to gain the advantages of both. Thus, the redundant Haar wavelet (or HTW) offers a simple, credible and very straightforward solution to alleviate time series boundary effect problem. Such an environment would keep the length of the wavelet components same as that of the original time series and this may lead to identify inherent signal characteristics that would be necessary to accurately investigate possible interactions between variables at a given time step.

This technique has been previously used in Renaud et al. [14], Zheng et al. [15], Bao et al. [16], Amjady and Keynia [17], Nguyen and Nabney [18], Jammazi and Aloui [19]. The results of these studies show that the use of this combination can significantly improve the prediction performance better than other traditional techniques. While all these researchers use the proposed method to improve the prediction performance of their models, in the present study we implement this new wavelet tool along with their three estimators namely wavelet variance, correlation and cross-correlation (CCF), for the first time under innovative aspects.

In particular, to ensure the robustness of the results for the stock-oil market's dynamic interactions, this study encompasses three different wavelet estimators namely wavelet variance, wavelet correlation and wavelet CCF designed as alternative and complementary tools. In this way, the wavelet sub-band decomposition can extract the relevant characteristics of a signal at different scales and demonstrate accurate localization of events. The wavelet variance captures the variances' distribution of the oil and stock markets across scales, enabling us to identify the contribution of each scale to the total variance. The wavelet correlation is a powerful tool for the detection of potential linkages among the two considered series and finally the CCF between the dual fine and coarse wavelet components allows better understanding of lead/lag inter-relationships between the stock and CO prices at short/middle and long term horizons.

In sum, we may argue that the two basic reasons why the wavelet is such an effective tool for our analysis are the followings: First, this paper focuses on the analysis of the co-movements among the CO changes and the stock markets in both short and long term horizons. As such, an analysis based on the frequency-domain may provide fruitful insights about the degree of dependence between two financial variables, recognized as key consideration for policy makers and investors. Second, the advanced ways, included in the HTW technique, to produce interactions results will most likely stimulate thoughtful reflection and debate emphasizing the validity of the conventional wisdom that oil prices drive the stock market. More precisely, this study differs a lot from the existing literature pertaining to the CO-stock market relationship because the CCF derived from the proposed wavelet method demonstrate excellent performance compared to the other methods by offering satisfactory solutions to numerous problems which we are often confronted with. On one hand, the method considers the whole information contained in the original series preserving the intrinsic characteristics of the data when decomposed into a scale-dependent set of components. On the other hand, it might seem a futile effort in trying to analyze inferences based on regression models as wavelet technique relies simply and directly on the information contained in the wavelet coefficients.

Finally, the paper is organized as follows. In Section 2, we provide a comprehensive review of literature. The major recommendations for selecting the appropriate wavelet decomposition along with the statistical properties of the HTW transform, the wavelet variance, correlation and CCF between two processes are presented in Section 3. The empirical results are presented in Section 4 along with their implications. Finally, Section 5 discusses the results, concludes the paper and gives some directions for further research.

2. Literature review

Hamilton [20] pioneered the literature on the relationship between oil price shocks and macroeconomic variables by declaring that oil price increases were a key factor in generating some post-war U.S. recessions. More precisely, he expanded on his first paper in a later one [21] and he found that nine out of ten World-War II U.S. recessions were preceded by large positive oil price hikes. Subsequently, the latest oil shock and its severe consequences have led researchers to address much ongoing

[2] For a review of the literature on the characterizations of financial time series, see Sowell, 2011.