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# Identifying the dynamic relationship between tanker freight rates and oil prices: In the perspective of multiscale relevance

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ABSTRACT

The tanker shipping market has been treated as the key extension of the world oil market and inevitably, its uncertainty is correlated to volatility of the oil market, besides supply and demand factors. Therefore, for improving operational management and budget planning decisions, it is essential to understand the inherent relevance between freight rates and crude oil prices. Taking time-dependent features into account, this paper focuses on the multiscale correlation between freight rates and oil prices. Given the complexity and mutability of tanker freight rate process, this paper first extracts the intrinsic mode functions from the original data using the Ensemble Empirical Mode Decomposition model and then reconstructs two separate composite functions: high-frequency and low-frequency components, plus the residual as the long-term trend. Secondly, correlations of the multiscale components of freight rates and oil prices are examined based on relevance structure. Empirical results show that tanker freight rates and oil prices exhibit different multiscale properties with true economic meaning and are significantly correlated in the medium and the long term when taking the relevance structure into account. These findings offer some useful information to better understand the correlations between these two markets and more importantly, propose a novel perspective to investigate the dynamic relationship between two markets.



## 1. Introduction

Crude oil, as a vital strategic commodity, is traded across the globe and this involves massive transportation infrastructures, including pipelines, tankers and storage facilities (Rodrigue et al., 2006). Internationally, tanker shipping is necessary to address the imbalances between oil supply and demand in different regions. Moreover, tanker shipping, as the central logistics, plays a crucial role in the management of the global supply chain in the oil industry (Alizadeh and Nomikos, 2004; Cheng and Duran, 2004). More importantly, tanker shipping is a service that provides “special” utility to the oil market and adds value to oil by moving it from surplus to deficit areas (Mayr and Tamvakis, 1999). Naturally, tanker shipping market can be treated as the key extension of the international oil market and inevitably, its uncertainty is closely correlated to volatility of the oil market, besides tanker supply and demand. Spontaneously, for improving operational management and budget planning decisions, it is essential to investigate the inherent dynamic relationship between tanker freight rates and oil prices.

Much effort has gone into the study of modeling the dynamics of tanker freight rates, in order to better support the operational decision-making for shipping assets under uncertainty (Batchelor et al., 2007; Engelen et al., 2006; Glen, 2006; Kavussanos and Alizadeh, 2002; Tvedt, 1997). Basically, shipping cycles inherent in the maritime industry propel freight rates to be mean-reverting in the long run (Stopford, 2008; Tvedt, 2003). Moreover, the assumption of inelastic demand and elastic supply can basically explain the phenomenon of both small and large volatilities clustering together because of small changes in the market balance (Strandenes and Adland, 2007). Besides, oil is not only the commodity being transported, but is also an essential component of the transportation cost. While oil prices may explain some of the variation and dynamics in maritime transport costs, other factors are also at play[1] (UNCTAD, 2010). Although the methods used to model the dynamics of freight rate processes vary in extant literature, the consensus is that freight rates are time-varying, non-linear and local non-stationary (Adland and Cullinane, 2006;

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[1] Summarized in UNCTAD (2010). These factors include, (a) demand for shipping services (e.g. trade volumes); (b) port-level variables (e.g. the quality of port infrastructure); (c) product-level variables (e.g. value/weight ratios and product prices); (d) industry-level variables (e.g. the extent of competition among shippers and carriers); (e) technological factors (e.g. the degree of containerization, size of ships and economies of scale); (f) institutional variables (e.g. legislation and regulation); and (g) country-level variables (e.g. attractiveness of export markets). This paper focuses on the relationship between oil price and freight rates, and specific analysis on these factors is beyond the scope of the present study.

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Adland et al., 2008; Goulielmos, 2009; Kavussanos, 1996; Kavussanos and Alizadeh, 2002; Tvedt, 2003; Xu et al., 2011). In brief, high complexity and mutability of the freight rate process make modeling of the inherent dynamics a challenging task.

Although a substantial amount of information is available on the dynamics of tanker freight rates, few studies have centered on the time-dependent properties of tanker freight rates as well as their relevance for oil prices. In related studies, Alizadeh and Nomikos (2004) investigated the causal relationship between WTI futures and price of imported oil considering transportation costs and found evidence of the existence of a long-run relationship between freight rates and oil prices in the US. Moreover, Hummels (2007) showed that maritime freight rates are highly sensitive to changes in oil prices. In a related study, Mirza and Zitouna (2009) examined whether effects of oil prices on transportation costs vary across different suppliers and buyers and the results showed a low elasticity of the correlation between freight rates and oil prices, ranging from 0.088 for countries close to the United States to 0.103 for faraway countries. With focus on the West African and U.S. Gulf Coast tanker shipping market, Poulakidas and Joutz (2009) examined lead–lag relationship between oil prices and tanker freight rates using cointegration and Granger causality analysis. Additionally, forces of supply and demand can make the relationship between crude oil prices and spot tanker rates ambiguous (Glen and Martin, 2005). Here the results showed that the effect of rise in real oil price on spot rate is negative and positive for 250,000 dwt and 130,000 dwt tanker vessels, respectively. The ambiguous relationship can be explained with two possible factors addressed in Glen and Martin (2005). First, oil prices rise when oil demand rises and this increases the demand for oil transportation which then generates a positive association. Second, oil price rise might be caused by a reduction in oil supply, which implies a fall in demand for oil transportation services and an expected fall in spot rates. Hence, both a positive and a negative correlation can be justified. This makes the dynamic relationship between freight rates and oil prices complicated.

Generally, both the long-term self-correcting mechanisms and short-term fluctuations of freight rates work in tandem. The interplay between short-term, long-term or seasonal forces leads to complicated and time-varying freight rate processes. Thus, we agree with Engelen et al. (2011) in that it is necessary to take up the time-dependent features when modeling formulation of freight rates. When considering the inherent complexity and mutability mix of original time series, Li et al. (2012) proposed a decomposition hybrid approach to divide the original data into a series of relatively simple but meaningful components according to the “decomposition and ensemble” principle (Wang et al., 2005; Yu et al., 2008). These works inspire us to decompose the tanker freight rates into different scales in terms of time–frequency, which can offer more information of the inherent dynamic properties of freight rates. Moreover, it provides a novel perspective to investigate the relationship between tanker freight rates and oil prices.

According to the “decomposition and ensemble” principle, a process of decomposition can be performed to divide the original data of tanker freight rates into a series of relatively simple but meaningful components. Considering the dilemma between difficulties in modeling and lack of economic meaning can be solved by some decomposition methods, Zhang et al. (2008) identified the economic meanings of the three components of oil prices. Similarly, we identify and define the economic meanings of the three components as long-term trend, medium-term pattern in low frequency and short-term fluctuation in high frequency, which helps to understand the underlying rules of reality by exploring data's intrinsic modes.

Of particular interest and novelty is to examine the inherent relationship between oil prices and tanker freight rates by introducing the concept and process of multiscale relevance. In the process of multiscale relevance, freight rates and oil prices can first be decomposed into intrinsic mode functions in the different and simple time frequencies by using the decomposition algorithm, Ensemble Empirical Mode Decomposition (EMD). Secondly, multiscale components are constructed in terms of low frequency, high frequency and residual, and accordingly, the economic meanings can be explored in three scales: short-term fluctuation, medium-term pattern and long-term trend. Then, correlations between the multiscale components of oil price and tanker freight rates are investigated under the relevance structure, which is different from previous works in terms of the overall dynamics of freight rates.

To sum up, this paper attempts to propose a new framework of multiscale relevance to analyze the inherent relationship between tanker freight rates and oil prices. Insights gained from the perspective of multiscales will help further clarify the inherent dynamics of freight rates and offer more information of the time-dependent relevance with oil prices. The rest of this paper is organized as follows. Section 2 describes the research methodology. Section 3 describes the data and empirical results are presented in Section 4. Finally, conclusions and directions for further research are given in Section 5.

## 2. Estimation methodology

This section describes a three-step analysis framework, which involves intrinsic mode function (IMF) extraction, multiscale component construction and multiscale relevance examined. In the proposed framework, the dynamic relationship can be divided into three separate scales: the long-term trend, medium-term pattern in low frequency and short-term fluctuation in high frequency, which has not been found in extant literature. The following subsections then give the detailed description of the three main steps.

### *2.1. Step 1: IMFs extracted*

In order to extract components at different scales which are in different time-frequencies from the original time series data, we adopt the Ensemble EMD method which is an empirical, intuitive, direct and self-adaptive data processing method designed especially for nonlinear and non-stationary data and are different from the simple parametric models. Ensemble EMD is a fully functional procedure based on diffusion models[2] that can be used to identify and estimate functions that govern the dynamics, as stated in previous research. Ensemble EMD is a substantial improvement of EMD and can better separate the scales naturally by adding white noise series to the original time series and then treating the ensemble averages as the true intrinsic modes (Huang et al., 1998; Wu and Huang, 2004).

As an efficient tool for identifying multiscale properties, EMD and Ensemble EMD have been widely used to extract true intrinsic modes from complex objects in the reality (Cummings et al., 2004; Huang et al., 2003; Xie et al., 2008; Zhang et al., 2008). In this paper, the decomposition algorithm, Ensemble EMD model, is adopted to decompose the original data, $x_t$ $(t = 1, 2,\ldots, T)$, into $n$ components $c_{j,t}$ $(j = 1, 2,\ldots, n)$. The $x_t$ and $c_{j,t}$ satisfy Eq. (1).

$$x_t = \sum\nolimits_{j=1}^{n-1} c_{j,t} + r_t \tag{1}$$

where n-1 is the number of IMFs and $c_{j,t}$ $(j = 1, 2,\ldots, \text{n-1})$ denote the $j$th intrinsic mode function, which must satisfy the following two conditions: (1) in each whole function, the number of extrema (both maxima and minima) and the number of zero crossings must be equal or differ at the most by one; and (2) the intrinsic mode functions must be symmetric with respect to local zero mean. Besides, the $n$th component $r_t$ is the final residual, which represents the central tendency of data series $x_t$.

[2] Summarized in Adland and Cullinane (2006) and Adland et al. (2008).