Applied Energy 155 (2015) 171–180

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

# Dynamic integration of world oil prices: A reinvestigation of globalisation vs. regionalisation

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## HIGHLIGHTS

- The dynamic integration of the world crude oil market is investigated.
- A time-varying average distance measurement and an ECM linked with a DAG are used.
- A new structural break of the relationship between regional crude oil prices is found.
- The world crude oil market is integrated before 2010 and then began to diverge.
- WTI became price setter before 2010, while Brent played a leading role since 2011.

## ARTICLE INFO

*Article history:*
Received 1 February 2015
Received in revised form 24 May 2015
Accepted 25 May 2015

*Keywords:*
World crude oil market
Integration
Time-varying correlation
Directed acyclic graph

## ABSTRACT

This study investigates the dynamic integration of the international crude oil market and explores the leading/lagging relationship between the world's major crude oils—WTI, Brent, Dubai, Tapis and Nigeria—using a time-varying average distance measurement and an error correction model combined with a directed acyclic graph technique. The results indicate a long-term equilibrium relationship between the major crude oil markets from 2000 to 2010, which supports the international crude oil market being integrated. The world's crude oil market began to diverge at the end of 2010, as demonstrated by the increasing average distance between the prices. WTI has been separated from the international crude oil market system and now reflects more local supply and demand situations. WTI behaved as the price setter before 2010, while Brent has played the leading role in the crude oil market since 2011. Conversely, Tapis always behaves as a price taker, following other crude oil prices.



## 1. Introduction

The crude oil market is an indispensable part of the economic system and is important to the entire industrial chain. Thus, it is widely considered a global concern [1–3]. Due to the globalisation of the oil industry and the success of oil futures trading, the various types of crude oil, located in different regions and priced by three major international benchmarks (WTI, Brent and Dubai), have prices that often tend to move together. This indicates that changes in one market are quickly transmitted to the other markets, regardless of geographic isolation; in particular, these markets tend to boom or crash in response to the same exogenous shocks, such as financial crises, wars and extreme weather. However, the price fluctuations of different crude oils are not always in line with each other, due to adjustments from local factors, specific geopolitical risks, energy policies and so on.

WTI is a relatively lighter crude oil of higher quality than Brent and thus generally has benefitted from a higher price (it has been traded at a premium of a dollar or two over Brent). However, this is no longer always the case. Since 2011, the price of WTI has been significantly lower than the price of Brent due to a supply and demand imbalance at Cushing, which is attributed to the abrupt production increase in the United States. Other factors include the sudden disruption of oil exports from Libya due to the Libyan war, as well as market expectations of bullish Brent prices being pushed upwards because of the escalation of the conflict in Syria and the 2011 Egyptian revolution. These more frequent geopolitical threats in the Middle Eastern and North African regions have boosted Brent prices and potentially driven the reversal in the price difference between WTI and Brent. The degree of integration of the world's crude oil market seems to have changed. Although WTI and Brent are generally considered the benchmarks of the international crude oil price, they still tend to respond to changes in local market conditions. Therefore, a reinvestigation of the globalisation of the world's oil market, with a focus on specific regional

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http://dx.doi.org/10.1016/j.apenergy.2015.05.117
0306-2619/

characteristics, has important economic implications. Under these new market circumstances, two main issues should be investigated. The first is whether the main crude oil prices have diverged, and the second is which crude oil price has behaved as a price setter. This analysis contributes to an understanding of the dynamic relationships between crude oil prices and provides insight into international market rules, with important policy implications for trading strategies and risk avoidance for market participants.

Research into the relationships between regional crude oil markets dates back to the 1980s when Adelman [4] claimed that the world's oil market was one great pool. Adelman observed that the world's oil market was highly globalised and integrated, a claim that Rodriguez and Williams verified [5]. Nevertheless, there is still controversy surrounding the convergence and divergence of the international oil market. Weiner [6] found that oil prices diverged in response to regional supply and demand shocks and local government policies; this research supported the hypothesis of regionalisation across oil markets using correlation and a switching regression analysis.

Entering the 21st century, the judgement that the crude oil market is globalised seems to be recognised in most of the literature. Kleit [7] extends the arbitrage technique and validates the convergence of regional crude oil markets. AlMadi and Zhang [8] find that there is a co-integrated relationship between four crude oil prices (WTI, Brent, Dubai and Oman) and suggest that the international crude oil market converges rather than diverges over the long term. Narayan et al. [9] also indicate strong presence of different oil price clustering in the oil futures market. Hammoudeh et al. [10] find that there is a co-integration relationship between different crude oils (WTI, Brent, Dubai and Maya), ignoring their properties and locations. Reboredo [11] investigates the dependence structure between different crude oil prices. The models demonstrate that crude oil prices respond with similar intensity to bull and bear markets and support the hypothesis of 'one great pool for the world crude oil market'. Liu et al. [12] and Li and Leung [13] find that China's crude oil market is also involved in the great pool of the world crude oil market. Giulietti et al. [14] adopt time-series and cross-section methods to verify that the overwhelming majority of crude oil prices have stable long term relationships. An et al. [15] analyse the co-movement between WTI and Daqing crude oil prices using a complex network approach. They find that the co-movement modes are clustered around a few critical modes during the evolution. Ji and Fan [16] investigate the evolution of the world crude oil market using graph theory and find that the degree of globalisation for the world crude oil market is becoming entrenched.

In the most previous literatures, the conclusion that the world crude oil market is integrated is verified based on data before 2010. However, regional crude oil markets do not converge all of the time [14]. Oil-related events have increased the uncertainty and complexity of the worldwide oil market. Regional crude oil prices responding to different events display obvious differentiation [17]. Charles and Darne [18] investigate the weak-form efficient market hypothesis for WTI and Brent. They find that the Brent market is weak-form efficiency while the WTI market seems to be inefficiency. Candelon et al. [2] analyze the tail dependence among regional oil markets and find that the integration level between crude oil markets tends to decrease during extreme periods. Zhang and Zhang [19] investigate the movement regimes of Brent and WTI prices using Markov regime switching model, finding that these two crude prices present inconsistent characteristics after the financial crisis. In the meantime, co-integration relationship tested in the previous literatures has ignored the potential structural breaks and time-varying characteristics between different crude oil prices. Therefore, in order to capture the possible changes and the dynamics of the relationship between regional crude oil prices, new empirical results are proposed to reinvestigate the characteristics of globalisation/regionalisation for the world crude oil market. WTI, Brent, Dubai, Nigeria and Tapis crude spot prices are selected as representatives of five different regions for analysis and comparison in this paper.

The main contributions are as follows: (1) a time-varying average distance is proposed to supply new evidence for market convergence or divergence and a new structure break of the integration of the world crude oil market is detected; and (2) a long-term co-integrated relationship between these crude oil prices is investigated using an ECM combined with a directed acyclic graph (DAG) technique, which can also reveal their contemporaneous causal structure and new pricing power for leading/lagging relationship.

The following section introduces the methodology, including a time-varying average distance measure and an ECM based on the DAG technique. The next section presents the sample analysis and time-varying relationships between different crude oil prices, while co-integration and contemporaneous causality results are discussed in the subsequent section. The final section contains the conclusions.

## 2. Methods

In this section, the described twofold approach is used to analyse the dynamic relationships between the five regional crude oil prices and to reveal the internal changes of integration in the international crude oil market. First, a time-varying correlation and average distance between regional crude oil prices are constructed, capturing the close-sparse linkages and dynamics of integration. Then, the possible structure break in the integration can be tested; second, an ECM, combined with the DAG technique, is built to identify the contemporaneous causal structure and verify the price setter in the world crude oil market.

### 2.1. Models for time-varying correlation estimation

To better model the time-varying dynamics of the relationships among different regional crude oil prices, a moving window technique is introduced in correlation as follows [16]:

$$C_{ij,t} = \frac{\sum_{m=t-l+1}^{t}(p_{i,m}-\overline{p_i})(p_{j,m}-\overline{p_j})}{\sqrt{\sum_{m=t-l+1}^{t}(p_{i,m}-\overline{p_i})^2 \cdot \sum_{m=t-l+1}^{t}(p_{j,m}-\overline{p_j})^2}} \quad (1)$$

where $C_{ij,t}$ is the correlation coefficient between crude oil markets $i$ and $j$ during the period between $t-l+1$ and $t$ with a window width $l$; $p$ is the crude oil price, while $\overline{p}$ is the average of $p$ during the period between $t-l+1$ and $t$. There are few recommendations in the literature on how to decide the optimal window width, which requires a balance between too small and too large window widths for robustness. Ultimately, we chose a window width of 250 days, which corresponds to approximately the number of working days in one year, moving along the time scale with one window-step length. With this specification, the dynamic correlation can be calculated recursively over time.

In addition, to further analyse the degree of synchronous crude oil price fluctuations, abnormal returns are introduced to capture the abnormal or excess behaviour of oil price changes. In this paper, AR of the crude oil prices are defined as the unexpected returns, losses or profits induced by non-fundamental-driven shocks, such as financial crises, wars, extreme weather and market-oriented information release (e.g., OPEC's announcements of production decisions or the depreciation of the US dollar). The AR are measured as the actual return of oil prices minus the normal return. The normal return is an estimation of what the return of the