CRUDE OIL MARKET EFFICIENCY: AN EMPIRICAL INVESTIGATION VIA THE SHANNON ENTROPY

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ABSTRACT. This paper evaluates the time-varying degrees of weak-form efficiency of the crude oil markets using the Modified Shannon Entropy (MSE) and the Symbolic Time Series Analysis (STSA) approach. Using daily data from May 20, 1987 to March 6, 2012 for two worldwide crude oil benchmarks (West Texas Intermediate and Europe Brent), our findings reveal that the weak-form market efficiency of two oil markets evolves through time, but with different time trends. Moreover, the WTI market appears to be less efficient than the Europe Brent. These results have several implications for commodity portfolio hedgers and policymakers.

JEL Classification: G14; G15; C87.

Keywords: Oil Prices; Information Theory; Shannon Entropy; Market Efficiency.

RÉSUMÉ. Cet article examine la dynamique de l'efficience faible des marchés pétroliers via l'entropie de Shannon et l'analyse des données symboliques. Nos résultats, obtenus sur la base de données journalières allant du 20 mai 1987 au 6 mars 2012 pour deux marchés de référence (le Brent européen et le West Texas Intermediate), montrent que le degré d'efficience, au sens faible, des marchés considérés évolue dans le temps, mais avec des tendances temporelles différentes. En outre, le marché du WTI semble être moins efficient que le marché du Brent. Ces résultats ont des implications directes sur les actions des gérants de portefeuille et celles des régulateurs de marché.

Classification *JEL* : G14 ; G15 ; C87.

Mots-clés : Prix pétrolier ; théorie de l'information ; entropie de Shannon ; efficience informationnelle.

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1. INTRODUCTION

Crude oil plays a fundamental role in the world economy as it is a decisive determinant of economic growth. According to the International Energy Agency (IEA) 2009 report, oil represents 36% of the world's total primary energy, 95% of all the energy used for transportation, from 1.5% to 2% of the world GDP, and from 6% to 8% of the world trade volume. It also serves as benchmark for the pricing of numerous financial instruments including futures contracts, options, and other oil-related products. Thus, understanding the price behavior in the crude oil markets, which are characterized by high volatility levels and strong upward drifts over the last decade, is essential to both investors and policymakers.[5] This volatile pattern can be explained by a number of factors including, among others, the law of supply and demand (Hagen, 1994; Stevens, 1995), and irregulars past/present/ future events related to weather, stock market conditions, economic growth, political aspects, and investors' psychological expectations (Yu *et al.*, 2008). Other unforeseen events such as wars, embargoes and revolutions have also substantial influences on oil prices (Tabak and Cajueiro, 2007). The combined effect of these events, which can be either bad or good news or both, may lead crude oil prices to fluctuate without relation to its fundamental value. All in all, the degree of informational efficiency of crude oil markets may be affected and exhibit time-varying nature.

In theory, a market is efficient if all available and relevant information is immediately reflected in the asset prices. This information is defined as anything that may affect asset prices so that they become unknowable in the present and random in the future. As a result, in a perfectly efficient market price forecasts are impossible since there are no accurate patterns to asset prices and the best is the random process. Also, no one can take advantage of the available information to generate abnormal profits. Given its important implications for market regulation issues, asset pricing, and portfolio allocation, the efficient market hypothesis (EMH *hereafter*) has been extensively examined by a large body of literature following the seminal works of Fama (1970, 1991), but the focus is mostly on stock, bond and foreign exchange markets.

To date, the question of whether crude oil markets behave efficiently has been examined by only a few studies. Green and Mork (1991) firstly discuss the issue of crude oil market efficiency by testing whether the price of a futures contract on crude oil is an efficient predictor of the *ex-post* spot price at the time of merchandise delivery, given that all the relevant information was available at the time when the contract was set up. Using the generalized method of moments, they find evidence of predictability in oil prices for the whole sample period 1978-1985.[6] But, when sub-sample periods are used, the results indicate the improvements of market efficiency as the amount of predictability tends to reduce

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5. Following the rapid expansion of the world economy, and Asian economies in particular in the aftermath of the 1997-1998 financial crisis and the 2001 internet bubble burst, crude oil markets have experienced an unprecedented boom period. On the spot market, the West Texas Intermediate (WTI) crude oil price closed at $20.74 per barrel on January 2002 and broke a record level of $133.93 per barrel on June 2008. Other crude oil benchmarks exhibited the same price developments.

6. Empirical analysis was based on monthly prices of Mideast Light and African Light/North Sea crudes.