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# Is the refining margin stationary?☆

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ABSTRACT

It has traditionally been assumed that the refining margin is stationary given that it is a linear combination of cointegrated time series, i.e., crude oil and its main refining products (mainly heating oil and gasoline). Following this reasoning, stationary models have been proposed to measure the refining margin. In this paper, we investigate the main empirical properties of several time series that measure the refining margin (or crack spread) using an extensive database of WTI, heating oil and unleaded gasoline futures prices traded on the NYMEX. The results show that there are serious doubts about the stationarity of the refining margin. Moreover, a non-stationary factor model is proposed and estimated to measure the refining margin, and in some cases, the model achieves better results than the traditional stationary models. This result has straightforward implications for valuation and hedging.



## 1. Introduction

The refining process converts 47% of crude oil barrels into gasoline, 24% into diesel fuel and heating oil, 13% into jet fuel oil, 4% into heavy fuel oil, 4% into liquefied petroleum gas (LPG) and 8% into other products such as asphalt.[1] Similar to crude oil, each of these products has a market price that is quoted in organized markets. Therefore, there is a relationship between refined product prices and crude oil prices that is known as the "refining margin" or "crack spread".

For simplicity, the crack spread is usually calculated by only taking into account prices for crude oil and the most important refined products, i.e., gasoline and heating oil. Therefore, the crack spread is usually expressed as an X:Y:Z ratio, where X represents the number of barrels of crude oil, Y represents the number of barrels of gasoline and Z represents the number of barrels of heating oil, subject to the constraint that X = Y + Z. Widely used crack spreads include 3:2:1, 5:3:2 and 2:1:1.

☆ This paper is the sole responsibility of its authors, and the views represented here do not necessarily reflect those of the Banco de España.

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[1] See the Oil Market Report (2006) developed by the International Energy Agency for more information about these issues.

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Most articles on the stochastic behavior of commodity prices focus on either crude oil or the refined products derived from crude oil rather than on the crack spread. In this paper, we focus on the crack spread. Unlike oil prospecting and production, refining is a margin business; a refining company buys oil and sells refined products (e.g., gasoline and heating oil) and makes a profit that is, in principle, independent of oil and product prices. In other words, a refining company's profit (i.e., the refining margin) is related to the difference between the prices of crude oil and the refined products. However, this difference does not necessarily decrease (or increase) when the prices of crude oil and its products rise (or fall). As a result, refineries face a significant risk when, for example, oil prices rise but product prices remain static or decline. It is therefore clear that refining companies must somehow protect their refining margin using derivatives contracts.

This risk faced by refining companies can result in unpleasant consequences that have been thoroughly studied in the literature, such as costs from financial distress (Myers & Smith, 1982, Smith & Slutz, 1985), external financing costs and decreased investment opportunities (Froot, Schwarfstein, & Stein, 1993) and liquidity constraints (Holmström & Tirole, 2000, Mello & Parsons, 2000). However, it is also important to consider tax incentives (see, for example, Smith & Slutz, 1985 and Graham & Smith, 1999). Therefore, the crack spread deserves to be independently analyzed, which is the main objective of this paper.

Previous studies, including those by Serletis (1992, 1994); Pindyck (1999); Gjolberg and Johnsen (1999); Asche, Gjolberg, and Völker (2003) and Lanza, Manera, and Giovannini (2005), provide evidence of unit roots and cointegration in the prices of crude oil and refined products. Dempster, Medova, and Tang (2008) analyze the properties of the crack spread between heating oil and WTI crude oil (with data from 1994–2005) and the location spread between Brent blend and WTI crude oil (with data from 1993–2005) and find evidence of strong mean reversion on the spreads. Based on this empirical evidence, Dempster et al. (2008) propose a model for the spread with two mean-reverting factors and provide two applications to a set of European options on these two spreads. Dempster et al. (2008) note that the correlation between two asset returns is difficult to model (Alexander, 1999; Kirk, 1995 and Mbanefo, 1997) and that, therefore, the crack spread should be modeled directly.[2] In a recent study, Mirantes, Población, and Serna (2012) show that crude oil, heating oil and gasoline are not only cointegrated but also share common long-term dynamics.

Nomikos and Andriosopoulos (2012) propose a mean-reverting spike model allowing for time-varying volatility modeled as an EGARCH process. They find the presence of a leverage effect for WTI, heating oil and heating oil-WTI crack-spread log-price returns. Nomikos and Pouliasis (2015) develop a multi-regime error-correction factor model of the dynamics of the joint evolution of commodity pairs' forward curves, with application to the NYMEX and ICE crack spreads and inter-commodity spreads. They find evidence in favor of the existence of a long-run relationship between level and slope factors, although curvatures are found to be mean-reverting to commodity-specific equilibria.[3]

In this paper, we use a more recent database (up to 2013) to investigate the empirical characteristics of three series, the 2:1:1, the crude oil-heating oil and the crude oil-unleaded gasoline crack-spread series. Surprisingly, the results show that crack-spread futures prices tend to be non-stationary. In fact, in the vast majority of cases, it is not possible to reject the null hypothesis of a unit root for crack-spread futures prices.

Based on this empirical regularity, a two-factor model is proposed in which the crack spread is determined by the sum of two stochastic factors: a short-term mean-reverting factor whose impact decays for long-dated futures contracts and a permanent effect, long-term, non-mean-reverting factor, whose predominant influence is on longer-dated contracts.

The proposed model to measure the crack spread is framed within the family of multi-factor models proposed by Schwartz (1997) and a series of related papers, including those by Schwartz and Smith (2000), Cortazar and Schwartz (2003), and Cortazar and Naranjo (2006). All of these multi-factor models assume that the log spot price is the sum of both short- and long-term components. Long-term factors account for the long-term dynamics of commodity prices, which are assumed to follow a random walk, whereas the short-term factors account for the mean-reverting components in commodity prices. Within this family of models, one of the most popular is the two-factor model proposed by Schwartz and Smith (2000). Specifically, the model that is proposed in this paper to measure the crack spread is an adaptation of the Schwartz and Smith (2000) model in which the refining margin is measured as the sum of two short- and long-term factors plus a seasonal component to account for seasonal effects in the crack spread along the lines suggested by Sorensen (2002).

Both models of the crack spread, i.e., the Dempster et al. (2008) model and the Schwartz and Smith (2000) model, are estimated using the Kalman filter method on an extensive database of the prices of WTI crude oil, heating oil and unleaded gasoline futures traded on the NYMEX. The estimation results confirm that in some cases (mostly in the case of the crude oil-unleaded gasoline crack spread), the non-stationary model outperforms the stationary model of Dempster et al. (2008) in terms of the out-of-sample fit to the observed futures prices. These results have straightforward implications in terms of valuation and hedging, for example, in terms of crack-spread option valuation.

[2] Furthermore, by directly modeling the crack spread, we not only avoid the problem of modeling the correlation between two commodity returns, but we also have a simpler model that has less parameters and is easier to estimate than a two- or three-commodity price model.

[3] Recently, there have also been many papers analyzing the relationship between crude oil prices and several stock market-related variables, such as Chinese stock markets (Chen & Lv, 2015), major asset classes (Turhan, Sensoy, Ozturk, & Hacihasanoglu, 2014), stock market returns (Zhu, Li, & Li, 2014) and stock prices (Fang & You, 2014), among others.