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Unit root properties of crude oil spot and futures prices

Svetlana Maslyuk [a], Russell Smyth [b,*]

[a] School of Business and Economics, Monash University, Northways Road, Churchill, Victoria 3142, Australia
[b] Department of Economics, Monash University, 900 Dandenong Road, Caulfield East, Victoria 3145, Australia

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ABSTRACT

In this article, we examine whether WTI and Brent crude oil spot and futures prices (at 1, 3 and 6 months to maturity) contain a unit root with one and two structural breaks, employing weekly data over the period 1991–2004. To realise this objective we employ Lagrange multiplier (LM) unit root tests with one and two endogenous structural breaks proposed by Lee and Strazicich [2003. Minimum Lagrange multiplier unit root test with two structural breaks. Review of Economics and Statistics, 85, 1082–1089; 2004. Minimum LM unit root test with one structural break. Working Paper no. 04–17, Department of Economics, Appalachian State University]. We find that each of the oil price series can be characterised as a random walk process and that the endogenous structural breaks are significant and meaningful in terms of events that have impacted on world oil markets.

1. Introduction

There is no uniform view about the trajectory of commodity prices, including crude oil, over time. Some theorists advocate deterministic trend models with either an upward (Simon, 1985) or downward (Singer, 1950; Grilli and Yang, 1988) trend for commodity prices relative to industry prices. In the former, a steady increase in commodity prices can be attributed to economic growth. In the latter a downward trend in commodity prices is due to deterioration in the terms of trade of commodities, higher total factor productivity in agriculture relative to industry (Jalali-Naini and Asali, 2004) or a decrease in transportation cost. Oil prices have exhibited cyclical behaviour (Jalali-Naini and Asali, 2004; Pindyck, 1999; Zivot and Andrews, 1992; Radchenko, 2005) and local trends (Cashin and McDermott, 2002). Oil prices have been very volatile, changing their trajectories and behaviour with respect to the economic situation. For industrial commodities including oil, the most volatile years were 1971 and 1989 (Cashin and McDermott, 2002). These years are important because the *frequency* of price movements increased substantially after 1971 (Cashin and McDermott, 2002, p. 22) and the *amplitude* of price swings increased after 1989. For example, Cashin and McDermott (2002, p. 22) found that although trends in prices were highly volatile, "price variability completely dominates long-run trends".

In addition, there is a very strong seasonal component, where oil prices are traditionally higher during winter than during summer. Since the end of the 1990s oil prices have been steadily increasing, reflecting rising demand for crude oil, particularly from developing nations. However, there is no dominant upward trend. Instead, oil prices exhibit large upward or downward swings primarily caused by "fluctuations in demand, extraction costs, and reserves" (Pindyck, 1999, p. 12). Any upward shifts in demand for oil or a rise in extraction costs will cause the spot and futures prices of oil to increase, and this might lead to a change in the slope of the price trajectories (Pindyck, 1999). After such swings, prices appear to revert to their long-run mean value or long-run marginal cost, which also appear to change over time. Moreover, "temporary price spikes … account for a large part of the total variation of changes in spot prices" (Blanco and Soronow, 2001, p. 83).

The purpose of this study is to examine unit root behaviour of crude oil spot and futures prices allowing for one and two structural breaks. Our analysis is based on weekly data for spot and futures prices for two market crudes; namely, the US West Texas Intermediate (WTI) and the UK Brent over the period January 1991–December 2004. One might expect oil prices to be stationary because of market dynamics, time lags between price changes and demand/supply imbalances (Pindyck, 1999; Postali and Picchetti, 2006). As discussed further in the literature review below, the previous studies that have found mean or trend reversion in crude oil prices have typically used annual data over periods ranging from 50 to 140 years. The value of such findings is limited because the lifespan of investment in a crude oil or natural gas field is about three decades (Postali and Picchetti, 2006). Thus, we examine whether crude oil prices have a unit root over a much shorter period, employing higher frequency data (weekly data). To realise this objective we employ Lagrange multiplier (LM) unit root tests with one and two endogenous structural breaks

* Corresponding author. Tel.: +61 3 9903 2134; fax: +61 3 9903 1128.
E-mail address: Russell.Smyth@BusEco.monash.edu.au (R. Smyth).

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proposed by Lee and Strazicich (2003, 2004). Compared with Augmented Dickey-Fuller (ADF) type tests that accommodate endogenous structural breaks, the LM unit root test with structural breaks has the advantage that the breaks are incorporated under the null. The LM unit root test with one and two structural breaks has only been applied to energy prices twice before and that was with annual data over a much longer period of time.

This article is structured as follows. Section 2 discusses the rationale for examining the stationarity of crude oil prices. Section 3 presents a literature review of studies of unit root tests applied to crude oil prices. Section 4 provides a methodological overview of the unit root tests that we apply in this article. Section 5 gives an overview of the data as well as containing a discussion of the potential break points. Section 6 presents the results. Section 7 concludes with a discussion of the implications of the findings, considers some of the limitations of the research and provides suggestions for future research.

2. Why does stationarity of crude oil prices matter?

The stochastic properties of crude oil prices have important implications for forecasting. As Pindyck (1999) pointed out, ideally we would like to be able to explain crude oil prices in structural terms because it is movements in demand and supply, and the factors that determine demand and supply, that cause prices to fluctuate. However, structural models are not very useful for long-run forecasting because it is difficult to come up with forecasts for the explanatory variables in such models, such as investment and production capacity and inventory levels, over long time horizons. As a consequence, industry forecasts of crude oil prices typically assume prices grow in real terms at some fixed rate. One possibility is that prices follow a random walk. Another possibility is that prices revert to a trend line, which implies that shocks to oil prices are temporary. As Pindyck (1999) noted, if oil prices are trend reverting this is consistent with crude oil being sold in a competitive market where price reverts to long-run marginal cost, which changes only slowly.

The stochastic properties of crude oil prices also have important implications for firms making investment decisions. The issue of whether it is preferable to model crude oil prices as a Geometric Brownian Motion (or some other related random walk process) or mean or trend reverting process is important because investments are irreversible and, as such, have option like characteristics. Baker et al. (1998) and Dixit and Pindyck (1994) show that different models of the pricing process carry important implications for investment and valuation decisions. Pindyck (1999, p.2) noted: "Simple net present value [NPV] rules are based only on expected future prices—second moments do not matter for NPV assessments of investment projects. But this is not true when investment decisions involve real options, as is the case when the investment is irreversible. Then second moments matter very much, so that an investment decision based on a mean-reverting process could turn out to be quite different from one based on a random walk". Research to evaluate oil and gas deposits has developed complex multifactor models. However, as Postali and Picchetti (2006) have stressed, if Geometric Brownian Motion is a reasonable proxy for the behaviour of crude oil prices, it is possible to find closed form solutions to a wide class of problems on real options without complex numerical procedures.

Examining whether crude oil spot and futures prices contain a unit root has important implications for investors. If crude oil spot and futures prices contain a random walk, it follows that the crude oil market is efficient in the weak form, meaning future prices cannot be predicted using historical price data. This implies that an uninformed investor with a diversified portfolio will, on average, obtain a rate of return as good as an expert. If the random walk hypothesis is rejected it follows that it is possible for investors to make profits using technical analysis. Rejection of the random walk null hypothesis, based on a unit root with structural breaks does not necessarily imply that crude oil spot and futures markets are inefficient or that crude oil spot and futures prices are rational assessments of fundamental values. However, such a result would highlight the important role that structural breaks can play in tests for unit roots and raise the important question of whether such trend breaks should be treated like any other, or differently, before crude oil spot and future prices are treated as either trend stationary or difference stationary (Serletis, 1992).

Finally, several studies have tested for a unit root in energy consumption or production (see e.g. Chen and Lee, 2007; Hsu et al., 2008; Narayan et al., 2008; Narayan and Smyth, 2007). These studies emphasise that if energy consumption or production is non-stationary, given the importance of energy to other sectors in the economy, other key macroeconomic variables would inherit that non-stationarity. As Hendry and Juselius (2000) note, "variables related to the level of any variables with a stochastic trend will inherit that non-stationarity, and transmit it to other variables in turn …. Links between variables will then 'spread' such non-stationarities throughout the economy". This issue is just as pertinent for crude oil prices as crude oil consumption or production. Studies have linked shocks to crude oil prices to output and inflation (Hamilton, 1996; Cunado and Perez de Gracia, 2003), the natural rate of unemployment (Caruth et al., 1998), movements in stock market indices (Sadorsky 1999; Papapetrou 2001) and fluctuations in business cycles (Kim and Loungani, 1992). From an economic viewpoint, if these macroeconomic series are non-stationary, business cycle theories, which describe fluctuations in output as temporary deviations from the long-run growth path will lose their empirical support.

3. Existing studies

It is common in the literature to explore the stochastic properties of crude oil prices prior to other econometric analysis. Papers that have applied conventional unit root tests such as the ADF (Dickey and Fuller, 1979) and Phillips and Perron (1988) (PP) tests and the KPSS (Kwiatkowski et al., 1992) stationarity test to WTI and Brent crude oil prices include Sivapulle and Moosa (1999), Serletis and Rangel-Ruiz (2004) and Taback (2003) among others. For example, Sivapulle and Moosa (1999) apply the ADF, PP and KPSS unit root tests to daily WTI spot and 1, 3, and 6 months to maturity WTI futures contracts covering the period 2 January 1985 to 11 July 1996. They found all four variables to be non-stationary based on these traditional tests. Serletis and Rangel-Ruiz (2004) applied ADF and PP tests to daily spot WTI crude oil prices from January 1991 to April 2001. They could not reject the unit root null. Taback (2003) tested whether Brent spot and 1, 2 and 3 months to maturity futures prices contain a unit root for the period January 1990–December 2000 using the ADF test and found that both spot prices and futures prices for 1- and 2-month contracts were non-stationary. Coimbra and Esteves (2004) tested the stationarity of Brent crude oil spot and futures prices by applying the ADF test to oil prices for the period January 1989–December 2003 as well as to a shorter period, which omitted the Gulf war, from January 1992 to December 2003. For both timeframes the null hypothesis of a unit root in crude oil prices could not be rejected.

Studies that have tested for a unit root in the prices of crude oils other than WTI and Brent include Alizadeh and Nomikos (2002) and Ewing and Harter (2000) among others. Alizadeh and