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Oil prices: Breaks and trends[☆]

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A B S T R A C T

This paper contributes to the literature of the stationarity of financial time series and the literature on oil and macroeconomics in several ways. First, it uses Kejriwal and Perron (2010) sequential procedure to endogenously determine multiple structural changes in real oil prices without facing the circular testing problem between structural changes and stationary assumptions of previous tests. Second, it performs a diagnostic check to detect the significance and magnitude of the potential breaks. Third, it uses the above information to test for the existence of stochastic trends in real oil prices, and fourth, it speculates about possible explanations for the break dates found in order to encourage further work and discussions. The exercise uses monthly data from January 1861 to August 2011.

1. Introduction

The behavior of oil prices and their trends have been a major economic concern at least for the last forty years. Pindyck (1978, 1980) is a first attempt to model the oil price behavior. More recently, the literature has turned into studying the integration order of energy prices. The importance of the latter is that, if oil prices are unit roots, then shocks will have permanent effects; yet, if they are stationary, they would be mean-reverting. There is some previous work done (Berck and Roberts, 1996; Ferreira et al., 2005; Pindyck, 1999) that concludes that oil prices follow a non-stationary path, but one problem with that work is that it does not take into account the existence of structural breaks, which strongly diminishes the power of the tests.

On the other hand, the literature on oil and macroeconomics offers powerful reasons to suspect the existence of structural breaks in oil prices. The earliest work in that literature suggested that oil prices have the unique feature that they precede real GDP (Hamilton, 1983, 1985, 2003). In fact, the work of Hamilton assumes that the oil market was a traditionally stable market that suddenly had a strong exogenous structural break around 1973, treating the oil market as an exogenous strange market, which behaved independently of the rest of the world's economy. However, the more recent literature does not give such a special behavior to oil prices, and have started a controversy on whether the oil market behaves like any other commodity market, responding to the global macroeconomic conditions instead of causing changes in the macroeconomics behavior (Chatrath et al., 2012; Herrera and Pesavento, 2009; Kilian, 2009). That apparent change in the behavior of the oil market suggests the existence of at least two structural breaks, one around 1973 and another one at a later date. This work does not aim to explain the reasons for those changes, but wonders instead on whether these breaks were isolated episodes or whether there have been other structural breaks in the oil market history since their beginnings.

When we allow structural breaks, the work done to test the existence of trends in oil prices show contradicting evidence. Using weekly data between 1991 and 1996, and allowing one break in 1994, Gulen (1999) finds non-stationarity for several spot prices. Serletis (1992) endogenously determines structural breaks using daily data and concludes against stationarity as well. Maslyuk and Smyth (2008), using weekly data over the period 1991–2004 and allowing for up to two structural breaks, also find evidence against stationarity. More recently, Ghoshray and Johnson (2010) were unable to reject the null of unit root using monthly data between January 1975 and December 2007, and allowing for two endogenous determined structural breaks.

On the other hand, Lee et al. (2006) examine the properties of eleven natural resource real price series between 1870 and 1990 allowing for two endogenously determined structural breaks and a quadratic trend, finding evidence against the unit root hypothesis

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for all price series. Lee and Lee (2009), using annual data between 1978 and 2006, and allowing for multiple breaks using the Bai and Perron (2003) procedure, find evidence of stationarity as well.

The previous work conducted to test for stationarity of energy prices has two important limitations. The first one is that the methods they use, except for Lee and Lee (2009), are based on Lee and Strazicich (2003), which allow for up to two structural breaks. Second, the procedure used to determine structural breaks suffers from the circular testing problem of structural changes tests and unit root tests. The problem is that to detect structural changes in the trend, it is necessary to know a priori whether the series was $I(0)$ or $I(1)$, since structural change tests entail different limit distributions in either case. If the series were $I(0)$ and we use the first difference of the series, they have very poor properties (Vogelsang, 1998). On the other hand, conducting inference about unit root tests requires information about the presence or absence of breaks since they can adversely affect both size and power properties of those tests (Carrion-i-Silvestre et al., 2009; Kim and Perron, 2009).

This paper contributes to this literature in several ways. First, we avoid the circular testing problem by using the Kejriwal and Perron's (2010) sequential procedure, from now on KP (2010), to endogenously determine multiple structural changes in real oil prices. In fact, KP (2010) allows us to endogenously select the number of breaks in trend and in level of univariate time series without any prior knowledge as to whether the noise component is stationary or not. The theoretical work on the circular testing problem started with the stability tests suggested by Vogelsang (2001) and Harvey et al. (2009). Perron and Yabu (2009) develop an alternative test with higher power and less size distortions using a super-efficient estimate of the sum of the autoregressive parameters in which the break date is unknown. In their procedure, the finite sample properties are improved by using a bias-corrected version of the OLS estimate as suggested by Roy and Fuller (2001), and the limit distributions for the tests in the $I(0)$ and $I(1)$ cases are almost the same across all permissible break dates. Based on Perron and Yabu (2009) and the sequential testing strategy of Bai and Perron (1998, 2003), KP (2010) develops a sequential procedure to test the null hypothesis of l changes against the alternative hypothesis of $(l+1)$ changes.

The second contribution is that it performs a diagnostic check through a conventional regression analysis to detect the significance and magnitude of the potential breaks detected. Third, by incorporating the information found on structural changes, it undertakes unit root tests to check for stationarity. In the exercise, we use oil price monthly data from January 1861 to August 2011. That is the longest time span ever used in this literature, and it allows better modeling of well-known breaks like that of 1974, when the OPEC cartel started to play a major role in the oil price setting. Fourth, based on the history of oil, we suggest a rationale for the changes in levels and trends detected. The paper continues in the following way. The next section describes the econometric methodology. Section 3 analyzes the data and show empirical results. Section 4 provides a rationale for the structural changes detected and Section 5 concludes.

Table 2
Unit root tests.

Test	Test statistic
Augmented Dickey–Fuller (1)	−9.44 (*)
Phillips–Perron (1)	−8.78 (*)
ERS DF-GLS (1)	−3.75 (*)
KPSS (2)	0.01
Elliott–Rothenberg–Stock (1)	0.60 (*)

(1) H0: There is a unit root.
(2) H0: The series is stationary.
(*) Rejected at 10% critical level.

2. Methodology

The KP (2010) Algorithm works in the following way. Suppose that we want to estimate a model for the data generating process (DGP) given by

$$y_t = x'_t \Psi + u_t, \tag{1a}$$

$$u_t = \alpha u_{t-1} + v_t, \tag{1b}$$

$$v_t = d(L) e_t. \tag{1c}$$

for $\alpha \in (0, 1]$ and $t = 1, \ldots, T$ with $d(L) = \sum_{i=0}^{\infty} L^i$, $e_t \sim i.i.d.\ (0, \sigma^2)$. Suppose also that x_t is an $r \times 1$ vector of deterministic components. The algorithm starts by estimating the l break dates $\hat{T}_1, \ldots, \hat{T}_l$ as global minimizers of the sum of squared residuals from the model with l breaks estimated by OLS

$$\left(\hat{T}_1, \ldots, \hat{T}_l\right) = \arg\min_{\left(\hat{T}_1, \ldots, \hat{T}_l\right)} SSR(T_1, \ldots, T_l).$$

The breaks are estimated using the dynamic programming algorithm proposed by Bai and Perron (2003). Second, define the $l+1$ intervals

$$I_1 = \left[0, \hat{T}_1\right], I_2 = \left[\hat{T}_1, \hat{T}_2\right], \ldots, I_{l+1} = \left[\hat{T}_l, \hat{T}\right].$$

Then, the algorithm tests for the existence of a break at interval I_i. Consider the regression $y_t = x'^{(i)}_t \Psi^{(i)} + u_t^{(i)}$, for $I_i = \left[\hat{T}_{i-1}, \hat{T}_i\right]$, where $x_t^{(i)}$ is a set of dummy variables representing the structural breaks. In this exercise we consider two models. The first for changes in levels for which $x_t^{(i)} = (1, I(t > \tau))$ and the second for changes in the deterministic trend for which $x_t^{(i)} = \left(1, I(t > \tau), t - \hat{T}_{i-1}, (t - \tau) I(t > \tau)\right)$,

Table 1
Break dates detected by the KP (2010) sequential procedure.

Break dates in level	$F_T(l+1\mid l)$	Critical values	Break dates in level and trend	$F_T(l+1\mid l)$	Critical values
January 1878	13.8	4.06			
January 1895	48.4	4.59	January 1895	16.4	4.11
January 1913	11.1	4.89			
April 1921	9.3	5.09	April 1921	25.5	4.34
March 1930	15.9	4.79			
February 1946	65.5	4.34			
February 1974	11.9	3.66	February 1974	11.9	3.66
			July 1979	20.3	4.79
			February 1986	18.7	4.89
			February 1991	20.8	5.09
			July 1998	4.9	4.59
			November 2008	12.9	5.29