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Non-linearities in the dynamics of oil prices

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ABSTRACT

Examining stationarity is of particular importance and represents the first step in empirical time-series research. Non-stationarity invalidates many of the results obtained from standard techniques and, therefore, requires special treatment. Because oil prices play an important role in affecting economic variables, this paper examines the stationarity of real oil prices (Brent, Dubai, WTI and the World) over the period 1973:2–2011:2. Real oil prices are expressed in the currencies of seven Asian countries (Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore and Thailand) and in the U.S. dollar. While using linear unit root tests without structural breaks shows no evidence of stationarity, allowing for breaks shows very limited evidence of stationarity. We argue that these results are attributed to the presence of nonlinearities in the behavior of oil prices. Testing for nonlinearity shows significant evidence of nonlinearity in all the cases with evidence of exponential smooth transition autoregression (ESTAR) nonlinearity-type in most cases. Applying unit root tests that account for two types of nonlinearities (smooth transition and nonlinear deterministic trends) reveals evidence of stationarity in all the cases.

1. Introduction

Oil prices have acquired increasing attention of both academicians and policy makers, especially after the oil shocks in the 1970s, and the recent sharp increases in oil prices between 2002 and 2008. Oil plays an important role in both oil-exporting and importing countries. In many oil-exporting countries, such as OPEC, national income heavily depends on crude oil exports. Thus, oil-price fluctuations can have a great impact on macroeconomic flows, such as incomes, savings, and current account balances. Recognizing that oil is the engine of economic activities, many studies have examined the impact of oil prices on different economic variables, such as exchange rates, growth, investment, stock prices, inflation and unemployment. For example, Hamilton (1983) finds a negative effect between oil price shocks and GDP and shows that oil shocks are responsible for economic recessions. Zhou (1995) finds that oil-price fluctuations play a major role in explaining real exchange rate movements. Chaudhuri and Daniel (1998) show that the nonstationary behavior of U.S. dollar real exchange rate is due to the nonstationary behavior of real oil prices. Bergvall (2004) finds that real oil price shocks explain most of the long-run variance of the real exchange rate in Norway and Denmark. Cunado and Gracia (2005) find that oil price shocks Granger-cause economic growth in Japan, South Korea, and Thailand. Chen and Chen (2007) show that real oil prices may have been the dominant source of real exchange rate movements in the G7. Park and Ratti (2008) find that oil prices negatively affect stock prices in the U.S. and 13 European countries. Jin (2008) finds a negative effect of oil price increase on growth in Japan and China. Rafiq et al. (2008) find that oil price volatility has a significant impact on unemployment and investment in Thailand. Korhonen and Juurikkala (2009) find that an increase in the real oil price appreciates OPEC's real exchange rates. Du et al. (2010) find a significant effect of oil prices on growth and inflation in China. Moreover, empirical work suggests that the increases in oil prices between 2003 and 2005 have contributed to a 1.5% decrease in world output (Rogoff, 2006).

Accordingly, investigating the stationarity of oil prices is a necessary step required prior to examining the effect of oil prices on economic variables. This is important because if the variables are non-stationary, the results obtained from standard regression analysis are largely invalid and, therefore, inappropriate (spurious results). Therefore, investigating the stationarity of oil prices is of great importance to policy makers. In fact, the ability of policy makers to make decisions and the reliability of the decisions will depend upon correctly specified models and how well these models capture the true dynamics of the fundamentals in question (Ghoshray and Johnson, 2010).

Empirically, a number of studies have examined the stationarity of oil prices using conventional unit root tests, such as the linear Augmented-Dickey Fuller (ADF) test. In these tests, rejecting the

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null hypothesis of unit root implies that the series is stationary. The majority of studies find that oil prices are nonstationary.[2] Among others, Amano and Norden (1998), Bekiros and Diks (2008), Bentzen (2007), Bhar et al. (2008), Chaudhuri and Daniel (1998), Cunado and Gracia (2005), Jahan-Parvar and Mohammadi (2011), Jawadi and Bellalah (2011), Lardic and Mignon (2008), Pindyck (1999), Razgallah and Smimou (2011), Zhang et al. (2008), and Zhou (1995) are unable to reject the unit root null for different oil prices. On the other hand, Moshiri and Foroutan (2006) find, using the ADF test and daily observation from April 1983 to January 2003, that the crude oil future prices are stationary. However, one problem with these studies is that they employ conventional unit root tests that lack power, especially in short samples. Postali and Picchetti (2006) argue that a sample size of more than 100 years of annual data would be required to reject the unit root null when the autoregressive parameter is close to one. Using conventional tests and annual data on international oil prices from 1861 to 1999, the authors are able to reject the unit root null for full sample, but not for sub-samples. Others argue that conventional tests lack power in the presence of structural breaks (Perron, 1989; Zivot and Andrews, 1992). Postali and Picchetti (2006) apply unit root tests with structural breaks and are able to reject the unit root null with two endogenous breaks and conclude that their inability to reject the unit root null for the sub-periods was due to disregarding structural breaks. On the contrary, Tsen (2011), using Zivot and Andrews (1992) unit root test that allows for an endogenously determined break and quarterly data from 1960 to 2009, is unable to reject the unit root null for the real oil price. Others use panel data and are unable to reject the unit root null. For example, Chen and Chen (2007), using monthly data from 1972 to 2005 and panel unit root tests, find that the real oil prices of Brent, Dubai, the World, and WTI are nonstationary with no evidence of structural breaks.

In addition, these studies assume that the data-generating process of oil prices is linear and hence, utilizes oil price data in linear forms. Recently, however, there has been an increasing interest in examining nonlinearity in key economic variables, such as exchange rates, interest rates and inflation rates, because if nonlinearity is present, then applying linear tests, such as the ADF test, may bias the results, leading to a high probability of accepting a false null hypothesis (see, for example, Balke and Fomby, 1997; Caner and Hansen, 2001; Enders and Granger, 1998; Pippenger and Goering, 1993). In particular, Pippenger and Goering (1993) argue that many economic relationships involve economic variables that have implicit transaction costs or arbitrage boundaries where arbitrage is too expensive and thus, does not take place. They examine the power of linear unit root tests in detecting mean reversion in economic variables to long-run equilibrium in the presence of transaction costs and find that the power of these tests may fall dramatically under threshold processes.

Along these lines, Cuestas and Regis (2010) employ nonlinear unit root tests to examine the order of integration of the S&P crude oil price index using daily observations for the period January, 1st, 1987–June, 10th, 2008. Applying Bierens (1997) unit root test which assumes nonlinear trend stationarity under the alternative hypothesis, the authors find that the oil price is stationary around a nonlinear deterministic trend.

Building on Cuestas and Regis' (2010) work, the objective of this paper is to use nonlinear tests to examine the stationarity of four oil prices: British (Brent), United Arab Emirates (Dubai), West Texas Intermediate price (WTI), and the World price of oil (World), which is the world's average price of crude oil. To achieve this, quarterly data is extracted from the IMF's International Financial Statistics online database over the period 1973:2–2011:2. The data contains the nominal exchange rate (defined as the market rate per U.S. dollar), the consumer price index (CPI), and oil prices. We perform a thorough treatment of the behavior of real oil prices by (1) testing formally for the presence of nonlinearities in the real oil prices expressed in the domestic currencies of seven Asian countries (Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore and Thailand) and in the U.S. dollar; (2) differentiating between symmetrical and asymmetrical types of nonlinearities; (3) examining the stationarity of the real oil prices using unit root tests that allow for two types of nonlinearities (smooth transition and nonlinear deterministic trends). The real oil prices in domestic currency are calculated by converting the U.S. dollar price of oil into domestic currency and then deflated by the domestic CPI (2005 = 100).[3] All variables are measured in logarithms.

We proceed as follows. Section two explains the rationale behind nonlinearity in oil prices. Section three presents the methodology. Section four provides the empirical results and Section five gives summary and conclusion.

2. The rationale behind nonlinearity in oil prices

In the aftermath of the oil shocks in the 1970s, the U.S. and other economies went into a recession. In view of that, many studies have examined the impact of oil shocks on different economic variables, in particular GDP. Early studies assume that the relationship between oil price shocks and economic activity is linear and that oil price increases and decreases have symmetrical effects on economic activity. These studies find a linear negative relationship between oil prices and economic activity (see, for example, Darby, 1982; Hamilton, 1983). For instance, Hamilton (1983) concludes that 7 out of the 8 postwar U.S. recessions were preceded by a sharp increase in the price of crude oil. However, the estimated linear relationship between oil prices and economic activity began to lose significance around the mid-1980s when the declines in oil prices were found to have smaller positive effects on economic activity than predicted by linear models (Jiménez-Rodríguez and Sánchez, 2004). This suggests that the linear specification may not be the appropriate functional form to represent the relationship between oil prices and economic activity. Accordingly, Hamilton (1996), Lee et al. (1995) and Mork (1989) introduced nonlinear transformations of oil prices to capture the complex relationship between oil prices and economic activity and to restore the negative relationship between oil price changes and economic activity. In particular, Mork (1989) proposes an asymmetric definition of oil prices and differentiates between positive and negative oil price changes. He finds asymmetry between the U.S. economic activity and oil price changes and that the effects of oil price increases were different from those of decreases, and that oil price decreases were not statistically significant. Lee et al. (1995), on the other hand, argue that the response of GDP to oil price shocks depends mainly on the stability of the oil price environment. In particular, an oil price shock in a stable environment is more likely to have a greater impact on GDP than in a volatile environment. Based on that, the authors propose another nonlinear measure of oil prices using GARCH models known as "volatility adjusted series of oil price." They find asymmetry for positive and negative oil price shocks. Hamilton (1996) argues that it is more appropriate to compare the current oil price with that during the previous year rather than during the previous quarter. He proposes another form of asymmetric oil price transformation termed as "net oil price increase (NOPI)."

Moreover, Akram (2004) points out to a nonlinear asymmetric relationship between the nominal exchange rate of the krone and oil prices. Huang et al. (2005) find that oil price shocks have asymmetric effects on economic growth in Canada, Japan and the U.S.

[2] Although many of these studies test a range of variables, only results related to oil prices are reviewed.

[3] Empirically, studies examining oil prices use either the U.S. dollar oil price or this price converted into domestic currency using the market exchange rate. The main difference between the two variables is that fluctuations in oil prices expressed in domestic currency may be due to exchange rate fluctuations and/or fluctuations in the national price level.