Energy Economics 59 (2016) 227–237

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

Dynamic structure of the spot price of crude oil: does time aggregation matter?

Hajar Aghababa [a,*], William A. Barnett [b]

[a] University of Kansas, Lawrence, KS, USA
[b] University of Kansas, Lawrence, KS and Center Center for Financial Stability, New York, NY, USA

ARTICLE INFO

Article history:
Received 31 May 2015
Received in revised form 10 July 2016
Accepted 26 July 2016
Available online 17 August 2016

JEL classification:
C22
Q43
C46

Keywords:
Nonlinearity
Energy market
Time series analysis
Crude oil prices

ABSTRACT

This paper assesses nonlinear structures in the time series data generating mechanism of crude oil prices. We apply well-known univariate tests for nonlinearity, with distinct power functions over alternatives, but with different null hypotheses reflecting the existence of different concepts of linearity and nonlinearity in the time series literature. We utilize daily data on crude oil spot price for over 26 years, as well as monthly data on crude oil spot price for 41 years. Investigating the monthly price of crude oil along with the daily price distinguishes the approach of this paper from existing studies focusing on the time series structure of crude oil price. All the tests detect strong evidence of general nonlinear serial dependence, as well as nonlinearity in the mean, variance, and skewness functions in the daily spot price of crude oil. Since evidence of nonlinear dependence is less dramatic in monthly observations, nonlinear serial dependence is moderated by time aggregation in crude oil prices but not significantly.

1. Introduction

The energy sector, in particular the petroleum market, has played a key role in the aggregate economy. The energy sector has historically been influenced by political disturbances. Over the last four decades, the price of petroleum has dramatically increased in response to a series of major events. For instance, during the political unrest in the Middle East, the price of petroleum increased to nearly $113 per barrel per day in May 2011 after being relatively stable at around $80 per barrel per day since the 2008 credit crisis. As a result of such shocks, a large number of studies have focused on the correlation between energy sector disruptions and aggregate economic activity. For example, see Hamilton (1983), Hamilton (2003), and Rotemberg and Woodford (1996). Moreover, short and long-run interactions between the energy sector and other key markets, such as stock markets, have also impacted the aggregate economy and have been discussed in the literature — See, e.g., Jawadi et al. (2010), El Hedi and Fredj (2010), Jawadi and Bellalah (2011) and Anoruo (2012).

As a result of the important role of oil price fluctuation in the aggregate economy as well as its interaction with other key markets, examining the dynamic structure of crude oil price is critical, which is the main objective of this study. In particular, this paper examines whether time series observations of the oil market are generated by a linear process or a nonlinear dynamic mechanism. The findings can help to choose appropriate model specifications that comply with the data generating mechanism. If we reject the null hypothesis of linearity for macroeconomic time series variables, then perhaps there would be serious misspecifications in the model by employing linear time series modeling (Ashley and Patterson, 1989).

Moreover, most studies have focused on daily prices of crude oil and other petroleum products when assessing the dynamic structure of crude oil price. There is little mention of nonlinearity at other time frequencies such as monthly observations. The studies that focus on daily observations of the energy market, such as Kyrtsou et al. (2009), have found evidence of nonlinear dependencies in energy market data. Our paper addresses that gap in the literature by incorporating two levels of time aggregation (daily and monthly data) to examine at which time aggregation level the stochastic dependence or nonlinearity cannot be detected in the price of crude oil. We incorporate well-known univariate tests for nonlinearity with distinct power functions over alternatives and tests different null hypotheses. We would like to examine at what time aggregation level nonlinear structure cannot be detected in the data generating mechanism of crude oil price. To do this, we employ nominal daily spot prices of West Texas Intermediate (WTI) crude oil (not inflation adjusted) for over 26 years, as well as monthly data on crude oil spot price

* Corresponding author at: 331 N Eaton Dr., Lawrence, KS 66049, USA.
E-mail addresses: hajar.aghababa@gmail.com (H. Aghababa), barnett@ku.edu (W.A. Barnett).

http://dx.doi.org/10.1016/j.eneco.2016.07.023
0140-9883/

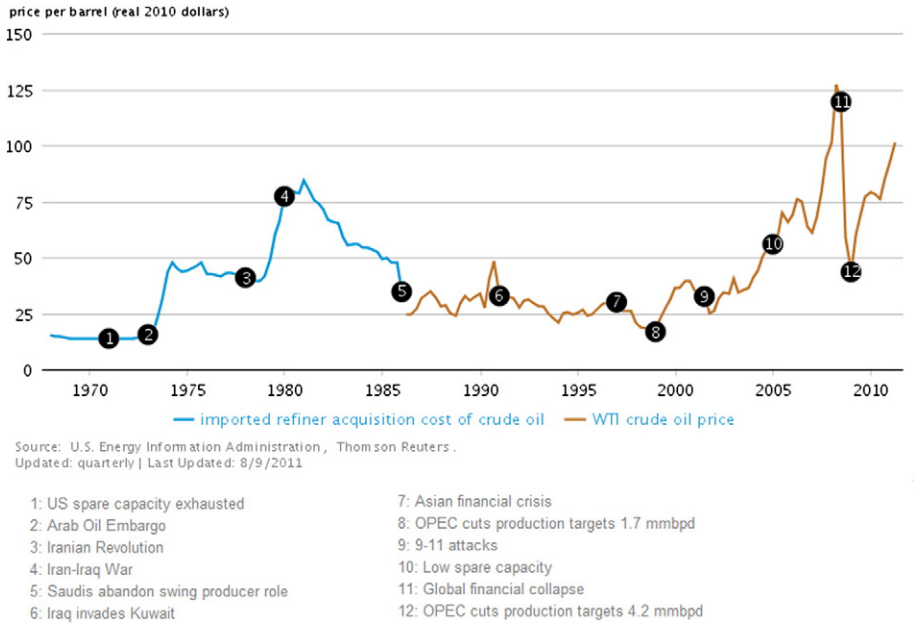

Fig. 1. Crude oil price reaction to variety of geopolitical and economic events.
Source: U.S. Energy Information Administration (2012), Thomson Reuters. "Crude Oil Prices React to a Variety of Geopolitical and Economic Events," *What Drives Crude Oil Prices.*

for over 40 years. Incorporating monthly observations as well as using conventional nonlinearity test in conjunction with more state of art methods distinguishes the approach of this paper from the existing literature.

We use the Brock et al. (1996) test, also known as the BDS test, with high power against numerous nonlinear alternatives to detect the general form of nonlinear dependence. Unlike other studies, we use multiple tests for nonlinearity using different definitions of the null hypothesis and different powers against alternatives to permit inference about different forms of nonlinearity. See Barnett et al. (1997), who find that the appearance of nonrobustness of nonlinearity tests across different tests is caused by different definitions of their null hypotheses, since as absence of nonlinearity in the mean, absence of third order nonlineary, absence of higher order terms in the Volterra expansion with martingale noise in the definition of the null, white noise in the definition, or pure white noise in the definition. The use of multipe tests provides insight into the nature of the nonlinearity, when nonlinearity is detectec.

This paper is organized as follows. Section 2 reviews the role of the energy market in the U.S. economy. Section 3 reviews the related literature. Section 4 describes the data and different unit root analyses. Section 5 discusses the inference methods, as well as providing the results of the nonlinearity tests on daily data and monthly observations. Summary, conclusion, and implication of the study are provided in Section 6.

2. The role of the energy market: a historical overview

A large body of literature has found that the U.S. economy is negatively influenced by major disruptions in the supply of crude oil and the consequent escalation in the petroleum price. In early 1970s to early 1980s, the price of oil increased considerably in response to a series of major conflicts in the Middle East. A result was a dramatic decline in the world supply of oil. The first fall in supply in that decade was experienced in late 1973, as a result of the oil embargo by the Organization of the Petroleum Exporting Countries (OPEC). Oil production was cut by five million barrels per day and the price of oil increased 400% in six months Sill (2007). The next dramatic increase in oil price occurred as a result of the Iranian Revolution, which began in late 1978 and resulted in a drop of 3.9 million barrels per day of Iran's crude oil production until 1981. In 1980, the Iran–Iraq war began, and by 1981 the OPEC production declined by seven million barrels per day from its level in 1978. The world oil price jumped from $14 per barrel in 1979 to more than $35 in 1981. The Persian Gulf Crisis in 1990 resulted in another sudden increase in crude oil prices. The price of crude oil, which had been relatively stable, escalated from $16 per barrels per day in July to more than $36 per barrel per day in September 1990 (Petroleum Chronology of Events 1970–2000, 2002).

After 1990, world oil demand increased dramatically during the global recovery period of 2003–2007 until the global financial collapse in 2008, when the oil price escalated to $134 per barrel per day in July 2008. Oil prices spiked again in 2011, as a result of unrest in the Middle East. The WTI spot price increased to nearly $120 per barrel per day in April 2011. Crude oil price reaction to a variety of global geopolitical events is shown in Fig. 1.

Oil price shocks have influenced the U.S. economy through different channels or other markets. As Hamilton (2011) noted, ten out of eleven postwar U.S. recessions were followed by a significant increase in price of petroleum.

High oil prices and energy supply disruptions can directly lead to economic downturns in the real business cycle. Moreover, oil price shocks also can influence the aggregate economic activity through monetary policies. If a rise in oil prices increases general price inflation, monetary authorities may adopt restrictive monetary policies, which could slow economic growth.[1]

Bernanke et al. (1997) argue that oil price shocks result monetary policy increases in interest rates, which cause downturns in the economy. Sajjadur and Serletis (2010) finds that oil price volatility also has an impact on macroeconomic activity. They argue that monetary policy not only reinforces the effects of oil price shocks on output but also contributes to the asymmetric response of output to oil price shocks.

[1] Restrictive policies can have only relative price effects without macroeconomic effects, if the central bank's commitment to price stability is completely credible, as happened in Switzerland during the late 1970s. In fact economic growth in Switzerland during those years benefited from the exceptional credibility of the central bank's commitment to non-accommodation of oil price shocks. But such strong reputational equilibrium in the face of major price shocks is unusual, because of the resulting distributional effects within the economy.