Computers & Industrial Engineering 63 (2012) 615–625

Contents lists available at SciVerse ScienceDirect

Computers & Industrial Engineering

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

System analysis approach for the identification of factors driving crude oil prices ☆

Qiang Ji *

Center for Energy & Environmental Policy Research (CEEP), Institute of Policy and Management (IPM), Chinese Academy of Sciences (CAS), P.O. Box 8712, Beijing 100190, China

ARTICLE INFO

Article history:
Available online 9 August 2011

Keywords:
Crude oil price
Financial crisis
Driving factors
VECM
DAG

ABSTRACT

A system analysis approach is proposed to identify the main factors driving international crude oil prices by integrating a partial least squares model, an vector error correction model and the directed acyclic graph method. The different mechanisms driving international crude oil prices during the oil price falling and rising periods are analyzed in three aspects: contemporaneous information transmission mechanism, explanatory power of factors for oil price trend and their contributions to the oil price volatility. The results show that the original mechanism of crude oil markets is destroyed by the 2008 financial crisis and the contemporaneous causality between oil price and various factors are significantly strengthened after crisis. Before the crisis, speculation was the main factor boosting oil price volatility in the contemporaneous and short run, while fundamental factors played important roles in the long run. After the crisis, spillover effect among different markets exhibits more obvious. Stock market, exchange rate market and commodity market make greater contribution, while US dollar index is the main factor affecting oil price volatility in the short and long run.

1. Introduction

Since the year 2004, international crude oil prices have exhibited dramatic volatility. Prices continued to increase sharply in the first half of 2008 and reached a record high of $147 per barrel. Since the global financial crisis was sparked by the American subprime crisis, oil prices plummeted to $30 per barrel. Even though no new oil crisis broke out, price fluctuations in such a short time were more severe than in any previous period in history.

An imbalance between oil supply and demand induced by wars caused the three oil crises during the 20th century. According to many researchers, supply and demand were the main factors driving oil price volatility. However, the latest oil price fluctuations present new characteristics. Traditional supply and demand factors do not offer sufficient explanations and factors affecting oil prices are more complicated. With the development of petroleum futures market, oil begins to present its financial attribute. Oil price fluctuations are not caused by imbalance between supply and demand most of the time, but affected by various market factors. OPEC's ability to dominate the crude oil price has diminished somewhat while world oil price is more set by market-orientated pricing mechanism. Single factor is hard to make sufficient explanations to the violent oil price volatility and all factors are in the game of oil price change. Therefore, factors affecting oil price trend are usually not consistent with those affecting oil price volatility. The driving mechanism has become more diversified and complicated.

Many previous literatures mainly focused on investigating the lagging causality between various factors and oil price using Granger causality test. However, with the development of information carriers and transaction technology, oil price is more sensitive to the release of market information, such as US dollar exchange depreciation, OPEC's output quota restriction policy, crude oil stock rise and so on which can cause oil price fluctuation correspondingly on the date of issue. In addition, crude oil market fluctuates severely with stock market and commodity market in the same time for the promotion of global market integration. The contemporaneous relationship between crude oil price and various factors has become more obvious, but fewer researches have worked on it before. Therefore, after the 2008 global financial crisis, researches on obvious changes in factors that drive oil prices and new influence mechanisms would further our understanding of the oil market in this new era and would help to predict oil price trends and control risk in the market.

Researchers have focused on various factors that influence international oil prices, such as the macroeconomy, financial markets, speculation, extreme event and supply and demand in oil markets. Chen (2009) used a structural VAR model to investigate three different shocks in the crude oil market. Analysis suggested that oil price movements have been driven by shocks arising from strong global aggregate demand and oil demand, whereas only minor contributions come from oil supply shocks. Cifarelli and Paladino (2010) found that speculation affects oil price

☆ Grant Sponsors: National Natural Science Foundation of China (NSFC) under the Grant No. 70825001.

* Tel./fax: +86 10 62542627.
E-mail address: jqwxnjq@163.com
URL: http://www.ceep.cas.cn

0360-8352/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cie.2011.07.021

dramatically in a modified CAPM model. Soytas, Sari, Hammoudeh, and Hacihasanoglu (2009) examined short- and long-run information transmission between world oil prices, Turkish interest rates, and domestic metal prices. They found that Turkish spot prices for precious metals, exchange rates and bond markets do not provide information that helps to improve forecasts of world oil prices in the long run. Ozbek and Ozlale (2010) analyzed real oil prices using a trend-cycle decomposition framework and assumed that cyclical terms are affected by global economic conditions. They found that economic shocks to oil price trends are more persistent. Zhang, Yu, Wang, and Lai (2009) proposed an EMD-based event analysis approach to estimate the impact of extreme events on crude oil price taking the Persian Gulf War in 1991 and the Iraq War in 2003 for example. Hamilton (2009) explored the causes of oil price changes in 2007–2008. Analysis revealed that price increases were caused by strong global demand and that speculation was another factor affecting price fluctuations. Ghouri (2006) concludes if other things are held constant, WTI is inversely related to the stock of petroleum products, combined petroleum products and crude oil, crude oil alone, crude oil and strategic petroleum reserves, total gasoline and total distillate stocks. Kilian (2009) proposed a newly structural VAR model to decompose the real crude oil price in four components. The analysis indicates that global demand not only affects contemporary oil price volatility, but also has great influence on prior oil price driven by supply. Du, He, and Wei (2010) investigated the relationship between world oil prices and the Chinese macroeconomy using multivariate VAR. The results show that world oil prices have a significant effect on economic growth and inflation in China.

Yang and Zhou (2010) propose an innovative empirical framework combining the cluster analysis, the principal component analysis (PCA), the directed acyclic graph (DAG) and structural vector autoregression (VAR) analysis to facilitate an in-depth search for systemic important financial institutions around the global credit crisis. This paper directly motivates us to propose a system analysis approach in this study. Our approach aims to identify the driving mechanism in the oil market by integrating a partial least squares (PLS) model, a vector error correction model (VECM) and the directed acyclic graph (DAG) method. The main contributions include: (1) The contemporaneous causal flow is identified and the contemporaneous causal structure is reconstructed to analyze the information transmission mechanism among crude oil prices and various factors. (2) A systems analysis approach is proposed to analyze the factors that affect oil price trend and oil price volatility separately. (3) Empirical research is made on the driving factors affecting international oil price before and after the financial crisis using the synthesis approach to get some important conclusions.

The following portion of this paper is organized as follows. Section 2 describes the framework of our synthesis approach and these modeling methodologies. Section 3 explains the driving factors for oil prices and data in details. Section 4 presents the empirical results. Section 5 summarizes the conclusions.

2. Synthesis approach

To better understand the driving mechanism of factors influencing crude oil prices, contemporaneous information transmission mechanism, explanatory power of factors for oil price trend and their contributions to the oil price volatility are analyzed. The complex processes are as follows (see Fig. 1):

1. By introducing various factors and the crude oil price in the PLS model, the explanatory power and the direction of the effect on oil price trend can be analyzed by estimating the model coefficients.
2. By filtering the factors according to the PLS results, one factor is selected among factors with similar effects. Using the filtered factors and the crude oil price, a VECM is constructed and test on the cointegration vector and the weak exogeneity of variables are carried out.
3. By constructing a DAG using the residuals correlation matrix for VECM variables in step 2, contemporaneous information transmission between the crude oil price and driving factors can be identified.
4. By restricting the contemporaneous causal structure in the VECM variance decomposition according to the DAG causal flow, the contribution of each factor to crude oil price volatility in the contemporaneous, short and long run can be calculated.

It should be noted that the purpose of filtration in step 2 is only to remove variables of similar character and effect on crude oil price and to reduce multicollinearity without affecting the VECM analysis (see Section 4.2). DAG construction relies on the VECM residuals. Conversely, the contemporaneous causal structure in the VECM variance decomposition is confined by the DAG. In our synthesis approach, three hierarchies supported by three models not only provide separate conclusions, but are also linked to each other in the construction process. By combining the interactive analysis from the three steps, a comprehensive analysis of the new characteristics of the factors that drive oil prices is presented.

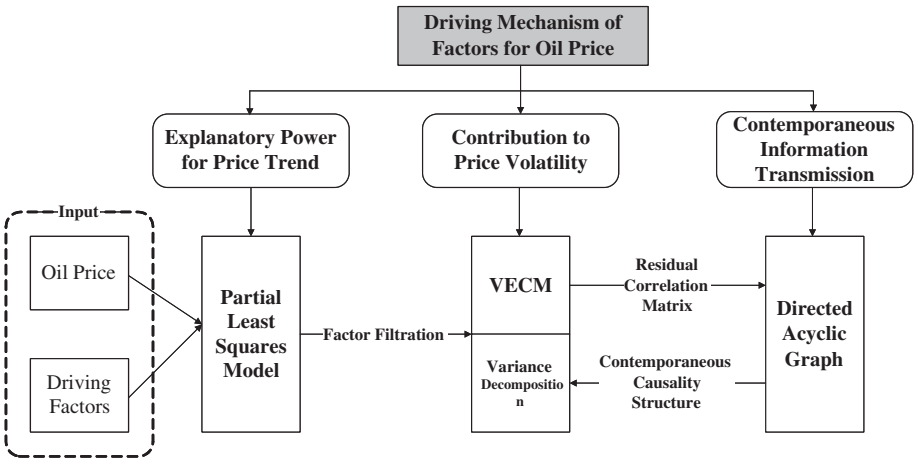

Fig. 1. Synthesis approach for identification of factors that drive crude oil prices.