Energy 109 (2016) 845–857

Contents lists available at ScienceDirect

Energy

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

Modeling the price relationships between crude oil, energy crops and biofuels

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ARTICLE INFO

Article history:
Received 19 July 2015
Received in revised form
29 February 2016
Accepted 4 May 2016

Keywords:
Crude oil
Biofuels
VAR (vector autoregression model)
VECM (vector error correction model)
Structural breaks

ABSTRACT

This paper explores the relationships between the prices of crude oil, corn and ethanol over the period from January 1986 to August 2015 using a Vector Autoregressive Model and Vector Error Correction Model. The structural breaks are endogenously determined using these variables and then the overall period is divided into three sub-periods. A long-run causal relationship among these three prices is found and depends on the level of the crude oil prices. The empirical results show that the corn price is driven by ethanol prices, but that the price of corn did not influence ethanol prices until 2005. However, there is a unidirectional causality that runs from crude oil prices to ethanol prices throughout the period. The empirical results indicate that a 1% increase in ethanol consumption could have reduced the crude oil price by 6.08% in the case of the U.S. during the period from 1987 to 2011, which implies that the development of ethanol production is one way of controlling inflation in relation to crude oil prices.

1. Introduction

The increased demand for petroleum for transportation, industry and electricity use all over the world has resulted in a rapid growth in oil prices in the last decade [16], which implies that energy prices could remain high in the future over the long term. Biofuels have therefore been brought into the energy market as an alternative to reduce the amount of carbon emissions released into the atmosphere as well as prevent energy prices from rising [7]. Since agricultural commodities such as corn, tubers, molasses, seaweed and soybeans are materials used to produce biofuels, the high bioenergy prices have been regarded as an important determinant of the high world agricultural prices [6]. This indicates that a bivariate relationship between the fuel and food markets has been extended to a more complicated trivariate relationship among the fossil-fuel, biofuel and agricultural food markets.

Crude oil prices have fluctuated over the past decade, rising from $22 in 2002 to $62 in 2005, and reaching an all-time high of $150 a barrel in 2008. Current oil prices are expected to rise even further as we face a strong upsurge in demand by emerging economies such as China and India under a constraint on the supply side [1]. However, the extraction of shale oil has increased dramatically since 2010 in the U.S., which has surprised the global crude oil market. The U.S. is estimated to have produced 4.49 million barrels per day (mb/d) of crude oil in 2015, which is about four times as much as in 2010. The growth of shale oil supply in the U.S. has forced the OECD (Organization of the Petroleum Exporting Countries) to hold its crude oil supply at 30 mb/d if it is to maintain its market power in the global crude oil market [22], and this has resulted in the downward trend in crude oil prices from 2014 onwards. In addition, OPEC currently could consider decreasing the crude oil supply to increase the global price of crude oil, and thus ensure a stable source of revenue for OPEC. That is, there could possibly be a return to high oil prices in the future. The fluctuations in crude oil prices have led to serious concerns in many countries because high oil prices may significantly affect the prices of agricultural commodities in many ways. For example, agricultural commodity prices are affected by high oil prices through the cost-push effects, such as through the use of energy-intensive fertilizer and fuel and transportation expenses over long distances. Hameed and Arshad [16] used a VECM (vector error correction model) and monthly data for the period from 1983 to 2008. Their findings confirmed that increasing oil prices contributed to the rise in the prices of agricultural food products. The link between food and fuel

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http://dx.doi.org/10.1016/j.energy.2016.05.016
0360-5442/

is also supported by Cooke and Robles [9]; who pointed to the existence of Granger causality between oil prices and agricultural commodity prices, but with a negative correlation. Such findings may arise due to a lack of control over structural breaks since the effects of oil prices on the agricultural market are more likely to be observed in the medium or long term than in the short term [9,15]. The evidence indicates that structural breaks exist in terms of analyzing the full sample, whereas Zhang et al. [44] found that oil prices have stronger effects on food prices in the sub-sample period of ethanol expansion than in the sub-sample period of ***pre***-ethanol expansion. Similarly, even though bio-ethanol products were produced prior to 2006, by using VECM and weekly data divided into two time periods, namely, 2003–2005 and 2006–2007, Campiche et al. [4] observed that the prices of agricultural commodities were only statistically significant when associated with crude oil prices between 2006 and 2007.

By contrast, there are demand-driven explanations. It is logical that people may search for alternative biofuels when faced with high oil prices, resulting in an increase in the use of agricultural feedstocks, which are the same materials required to produce biofuels [14]. Given the limited agricultural acreage, the upward shift in biofuel demand might create an incentive to produce more biomass feedstocks, which in turn might lead to other agricultural commodities used for food being disregarded by farmers, and, as a result, reinforce the price volatility in the agricultural market [14,29]. Using co-integration analysis, Ciaian and Kancs [7] found that the relationship between oil and food prices is more likely to be affected by biofuel prices than the cost of production. It has been argued that biofuel development is perhaps the main reason behind the increase in agricultural product prices [20,25]. In other words, the introduction of biofuels, which helps reduce U.S. dependence on imported crude oil, has strengthened linkages between fuel and the food market. Mitchell [25] contended that the increase in food prices was 70–75% linked to the increase in biofuel production, as confirmed by supporting data gathered between 2002 and 2008. Chen et al. [6] found that the growth of corn- and soybean-based biofuels boosted agricultural food prices, according to data gathered over the 1983–2008 period. On the other hand, Lazear [19] asserted that crops used for biofuel production are only responsible for a small portion of the total food price. Similarly, Mueller [26] inferred that the influence of biofuel production on increasing food prices ranged from approximately 3%–30%. This implies that the magnitude of the increase in biofuel production and its effects on food prices is an interesting topic to investigate.

However, without biofuel development, oil prices would have increased even more [20]. The findings show that a mixture of 90% gasoline and 10% ethanol would have lowered the prices of gasoline by between $0.19 and $0.50 [27]. Du and Hayes [10] found that bioethanol production reduced gasoline prices by an average of $0.29 per gallon from 2000 to 2011 in the U.S., whereas the Midwest region of the country appeared to be the most highly affected. Based on their study, a substantial reduction in gasoline prices was found in terms of the highest amount of ethanol production. Similarly, according to the Renewable Fuels Association [36], the price of gasoline is affected by the production of bioethanol, effectively reducing gasoline prices to a range of $0.5–$1.5 per gallon. The study also shows that crude oil prices would be approximately $15–$40 a barrel higher if there were no bioethanol production additives. It is because the price impact of bioethanol use can be regarded as a positive shock to the gasoline supply [23]. Not only do high oil prices breach a threshold level, making ethanol competitive with crude oil, but they also generate normal market conditions within the corn market [28]. Due to the linkages between agricultural commodities and bioenergy, bioethanol production might eventually become a tool used to stabilize corn prices. Natanelov et al. [29] found that corn prices would be stabilized by bioethanol production in relation to crude oil prices when crude oil prices were maintained at a threshold level of $75 per barrel in the U.S.

The above analysis of the bivariate relationship between fuel and food is rapidly becoming a focus of attention in existing studies. There is limited knowledge, however, of the trivariate relationship between fossil-fuel, biofuel and agricultural commodity prices. Therefore, the aim of this paper is to investigate the linkages and transmission patterns among crude oil, corn and ethanol prices. To investigate the trivariate relationship among these price series, both VAR (vector autoregression) and the VECM (vector error correction model) are applied using monthly data from January 1986 to August 2015. The VAR and VECM models are based on a flexible approach, which allows for the existence of endogeneity in the three price series in a regression equation. In addition, since structural break problems caused by the changes in any of the three price series could occur, this study further employs the unit root test with two endogenously determined structural breaks proposed by Clemente et al. [8]. The structural breaks are endogenously determined using the variables, and then the overall period is then divided into sub-periods. Furthermore, a demand function approach for ethanol is used to strengthen our findings based on the ARDL (autoregressive distributed lag model). The period of analysis further helps us to examine whether the degree of interdependence across markets has changed over time, and whether changes in biofuel mandates have affected the nature of the links between the bioenergy and agricultural markets. In addition, it is acknowledged that many countries have proposed policies with a view to developing alternative biofuels to reduce their reliance on crude oil and consequently help stabilize corn prices [29]. Thus, our findings might effectively provide information on the policy implications of price stabilization in the energy and food markets.

The remainder of this study is organized as follows. Section 2 introduces the data sets and econometric methodology for all tests. Sections 3 and 4 present the empirical results. Section 5 concludes and discusses the policy implications.

2. Data sets and tests

2.1. Data sets

This study explores the relationships between the prices of crude oil, corn and ethanol. Monthly time series data observed from January 1986 to August 2015 are used in the analysis. The definitions of the three variables are illustrated as follows. With respect to the crude oil price, two different crude oil prices have been commonly used in the literature: Brent (London) and West Texas Intermediate (WTI, New York). We employ WTI as our crude oil time series rather than Brent, not only because WTI is more sensitive to and is therefore the fastest reflection of the global oil price, but much of the existing literature has used WTI in understanding the relationship between crude oil prices and agricultural prices (see, for example, [4,44]). For bioenergy, ethanol has been the major bioenergy alternative produced around the world (Energy Information Administration, EIA). According to the Renewables Global Status Report [35]; the U.S. is the largest producing and exporting country for ethanol in the world (i.e., the U.S. exported 13 billion liters in 2010) and, for this reason, the U.S. price of ethanol has a stronger influence on the global pricing of ethanol than the EU or Brazilian prices of ethanol [21]. We therefore obtain the data regarding this measure following Serra et al. [38] and the information on the U.S. ethanol spot price is taken from Nebraska (U.S.) in our analysis. In addition, we make use of spot data for corn prices obtained from the Chicago Board of Trade (CBOT, U.S.) for the crop