Journal of Natural Gas Science and Engineering 36 (2016) 734–746

Contents lists available at ScienceDirect

Journal of Natural Gas Science and Engineering

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

How regional natural gas markets have reacted to oil price shocks before and since the shale gas revolution: A multi-scale perspective

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ARTICLE INFO

Article history:
Received 28 July 2016
Received in revised form
11 October 2016
Accepted 6 November 2016
Available online 9 November 2016

Keywords:
Crude oil price
Regional natural gas price
Fluctuation transmission
Ensemble empirical mode decomposition
Vector autoregression

ABSTRACT

Using the ensemble empirical mode decomposition and the vector autoregressive model, this paper investigates the impact of oil price changes on North American and European natural gas markets from a multi-scale perspective. In order to identify the impact of the North American shale gas revolution, the data is divided into two sub-periods: the pre-revolution period (2 January 1998–31 December 2005) and the post-revolution period (1 September 2009–20 May 2016). First, at the original data level, we found that the impact of oil price shocks on the North American gas market has become weaker since the shale gas revolution, whereas the shock effect on the European gas market has become stronger. Secondly, looking at the North American market, oil price shocks caused short-term fluctuations only before the shale gas revolution, whereas, in the medium term, they have had a significant impact both before and after the revolution, due to significant events with medium-term effects. From the long-term perspective, oil price shocks can lead to positive changes in the trend of the natural gas market both before and after the revolution. Thirdly, with regard to the European gas market, the impact of oil price shocks has been significant only since the shale gas revolution in the short and medium term, whereas, in the long term, shocks from the crude oil market resulted in a negative change in the trend of the natural gas market just before the shale gas revolution. These findings, based on the information gathered from these multiple time scales, may help energy policy makers, energy traders and financial investors make effective decisions related to risk management and investment.

1. Introduction

In recent years, the demand for natural gas has increased rapidly in many countries across the world (Economides and Wood, 2009). This has increased these countries' reliance on natural gas trading activities, leading to an increased risk of natural gas price fluctuations. As the structural mechanism of the natural gas market has evolved, the North American and European markets have gradually moved from a highly regulated environment to a deregulated one with significant price fluctuations (Ergen and Rizvanoglu, 2016). As a result, financial investors, trading participants and natural gas industry producers face increasingly significant price fluctuation risks in natural gas markets. Market participants and policy makers require a comprehensive understanding of the inner mechanisms underlying different regional natural gas price fluctuations in order to manage increased exposure to risk.

The fluctuations in natural gas markets reflect changes in crude oil prices, seasonality, natural gas inventories, hurricanes and other major events. Many scholars have suggested that crude oil prices were the main driving factor behind recent severe demand shocks experienced by natural gas markets (Asche et al., 2006; Ates and Huang, 2011; Brown and Yücel, 2008; Hartley et al., 2008; Nick and Thoenes, 2014). Accordingly, this paper focuses on the impact of crude oil price shocks on the North American and European natural gas markets. As the dynamic relationship between the crude oil market and regional natural gas markets is very complex, crude oil price and natural gas price fluctuations evidence multi-scale features, particularly with regard to the fact that the internal drivers of the fluctuations differ according to different time scales (Liu et al., 2015). Are the response mechanisms of regional natural gas markets to shocks in the crude oil market the same for different time scales? And, if not, what are the price risk

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http://dx.doi.org/10.1016/j.jngse.2016.11.020
1875-5100/

transmission mechanisms from the crude oil market to regional natural gas markets at these different time scales? By answering these questions, we can better understand the nonlinear dynamic relationships between crude oil prices and regional natural gas prices from a multi-scale perspective. This would help energy policy makers, trade participants and related financial investors to understand operational rules and price fluctuation risk in the natural gas markets.

A number of researchers have analysed the fluctuation risk transmission mechanism between the crude oil and natural gas markets. Ewing et al. (2002) showed that there was a significant asymmetric fluctuation transmission effect between crude oil and the North American natural gas market. Pindyck (2004) analysed the existence of interactions between natural gas and crude oil price fluctuations since 1990. Tonn et al. (2010) found that the price fluctuations of crude oil futures and North American natural gas price were not always interdependent. Ramirez and Karali (2014) showed that there was a two-way fluctuation spillover effect between crude oil and natural gas prices. Ji et al. (2014) found that crude oil price fluctuation had a negative impact on natural gas import prices in the three distinct regional markets and that the response of natural gas import prices to increases and decreases in crude oil prices reflected an asymmetrical mechanism. Yoncu and Bahramian (2015) reported a bidirectional causality relationship between natural gas prices and crude oil prices in the European market. Lin and Li (2015) showed that fluctuation in the crude oil market seems to spillover to the natural gas market, and vice versa, in both the North American and the European markets, and that fluctuations in the Japanese natural gas and oil markets appeared to be independent of this.

Some researchers have looked at how other factors influence natural gas price fluctuation. For example, Henning et al. (2003) analysed the drivers of natural gas price fluctuation, mainly including weather, fuel switching, crude oil, natural gas end-use demand and speculative factors. Linn and Zhu (2004) found that the release of the weekly natural gas inventory report had a significant impact on natural gas price fluctuation. Serletis and Shahmoradi (2006) analysed the determinants of natural gas futures price fluctuations for the New York Mercantile Exchange (NYMEX) Henry Hub, finding that both the seasonality and open positions had significant impact. Mu (2007) suggested that weather had a significant impact on the price fluctuation of natural gas futures. He also reported that natural gas price fluctuation was significantly higher when the natural inventory reports were released, indicating that information on market fundamentals had important implications for natural gas price fluctuation. Mastrangelo (2007) found that the fluctuation of Henry Hub natural gas spot prices exhibited strong seasonal characteristics and that changes in natural gas storage could also affect fluctuation levels. Suenaga et al. (2008) analysed NYMEX natural gas futures prices using a partially overlapping time series model, showing that the natural gas price fluctuation had a close relationship with seasonal demand and storage. Roesser (2009) explored the factors affecting natural gas price fluctuation, including weather, domestic production, storage, imports, infrastructure constraints, domestic and global demand, the correlation between oil and gas prices, the value of the dollar and commodity speculation factors. Chiou-Wei et al. (2014) analysed the impact of the weekly natural gas inventory reports released by the US Energy Information Administration (EIA) on the behaviour of US natural gas futures and spot prices. Martínez and Torró (2015) showed that European natural gas market price fluctuation had obvious seasonal effects and that this fluctuation was significantly higher in winter than in summer. Ergen and Rizvanoglu (2016) reported that natural gas price fluctuation was significantly higher both when the natural gas and crude oil inventory reports were released and in winter. Some academics have also explored the relationship between trade and the price fluctuation of natural gas futures, showing that the natural gas trade had a significant effect on the price fluctuation of natural gas futures (Chevallier and Sévi, 2012; Herbert, 1995).

As shown above, research literature to date has looked mainly at the response of the natural gas market to the impact of crude oil price fluctuations, weather and seasonality, and the information inventory reports taken from the original data level. There has been little research on how crude oil price shocks impact regional natural gas markets from a multi-scale perspective. The dynamic multi-scale relationship between crude oil prices and regional natural gas prices is an area that needs attention as it may offer new evidence on the nexus between the crude oil and regional natural gas markets. In addition, some studies have shown that the North American shale gas revolution may affect the complex dynamic relationship between crude oil prices and regional natural gas prices (Caporin and Fontini, 2016; Geng et al., 2016; Potts and Yerger, 2016). The North American shale gas revolution could lead to a transient separation of North American natural gas prices from crude oil prices (Erdős, 2012; Loungani and Matsumoto, 2012; Ramberg and Parsons, 2012). As a result, this empirical analysis has been conducted for two sub-periods to test the impact of the North American shale gas revolution. The pre-revolution period is defined as the period between 2 January 1998 and 31 December 2005, whereas the post-revolution period extends from 1 September 2009 to 20 May 2016. This paper makes two main contributions to research in the area: (1) The paper applies a multi-scale analysis to explore the fluctuation risk transmission mechanisms from the crude oil market to regional natural gas markets, giving a comprehensive understanding of the inherent drivers of the transmission mechanisms at different time scales; and (2) the paper looks at the impact of the North American shale gas revolution on risk transmission mechanisms from the crude oil market to regional natural gas markets.

The rest of this paper is structured as follows. Section 2 describes the methodology and data used in this study. Section 3 provides the empirical results and discussion. Section 4 draws the main conclusions and proposes some policy implications.

2. Methodology and data

In this study, the ensemble empirical mode decomposition (EEMD) method was first used to decompose crude oil and regional natural gas price returns in order to capture the different fluctuation features of the original series at high and low frequencies. The vector autoregression (VAR) model, impulse response function and variance decomposition were then used to analyse the impact of crude oil price shocks on natural gas price returns in North America and Europe according to different time scales.

2.1. The decomposition model for oil and gas price returns

In terms of multi-scale analysis, the EEMD method provides a way to circumvent the time-frequency characteristics hidden in the original signals. The EEMD method can decompose crude oil price and natural gas price return series into different scales, which enables us to identify the fluctuation characteristics of crude oil prices and natural gas prices at different time scales. In particular, the economic implications of different fluctuation modes can be identified through the analysis of extracted components at different time scales (Zhang et al., 2008).

In practice, crude oil and regional natural gas price returns were calculated for further analysis using two formulae: