Physica A xx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Physica A

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

Visibility graph network analysis of natural gas price: The case of North American market

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HIGHLIGHTS

- The natural gas price visibility graph network is established.
- The natural gas price series is of long-range negative correlation fractal features.
- The network is of small-world and scale-free properties simultaneously.
- Impacts of the hubs and the underlying mechanisms are analyzed.

ARTICLE INFO

Article history:
Received 3 January 2016
Received in revised form 6 April 2016
Available online xxxx

Keywords:
Natural gas spot price
Visibility graph network
Time series
Power-law distribution
Small-world characteristics

ABSTRACT

Fluctuations in prices of natural gas significantly affect global economy. Therefore, the research on the characteristics of natural gas price fluctuations, turning points and its influencing cycle on the subsequent price series is of great significance. Global natural gas trade concentrates on three regional markets: the North American market, the European market and the Asia-Pacific market, with North America having the most developed natural gas financial market. In addition, perfect legal supervision and coordinated regulations make the North American market more open and more competitive. This paper focuses on the North American natural gas market specifically. The Henry Hub natural gas spot price time series is converted to a visibility graph network which provides a new direction for macro analysis of time series, and several indicators are investigated: degree and degree distribution, the average shortest path length and community structure. The internal mechanisms underlying price fluctuations are explored through the indicators. The results show that the natural gas prices visibility graph network (NGP-VGN) is of small-world and scale-free properties simultaneously. After random rearrangement of original price time series, the degree distribution of network becomes exponential distribution, different from the original ones. This means that, the original price time series is of long-range negative correlation fractal characteristic. In addition, nodes with large degree correspond to significant geopolitical or economic events. Communities correspond to time cycles in visibility graph network. The cycles of time series and the impact scope of hubs can be found by community structure partition.

1. Introduction

The development of low-carbon energy has significantly caught up in most countries helping to cope with global warming and ensuring energy security. Natural gas, is considered as the bridge to a low carbon future and its price volatility has

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http://dx.doi.org/10.1016/j.physa.2016.06.051
0378-4371/

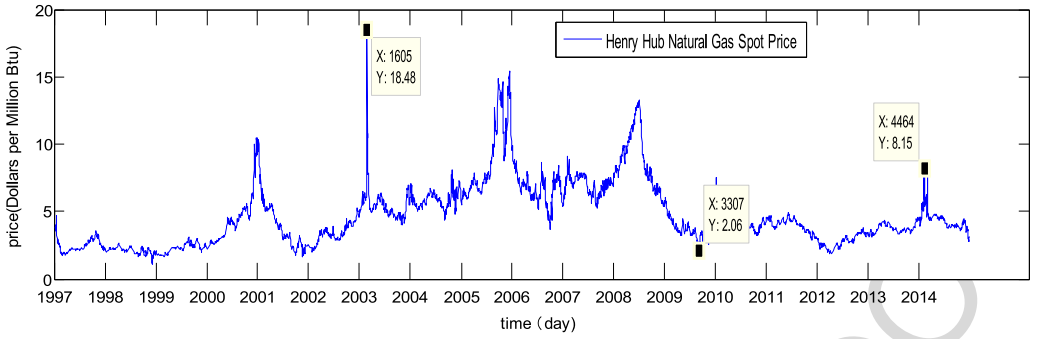

Fig. 1. Henry Hub natural gas spot price.

great influence on global economy. Natural gas reserves are abundant and its exploration is also promising. In 2014, the world's proven natural gas reserves were about 187.1 trillion cubic meters with reserve-production ratio of 54.1%.[1] The International Energy Agency (IEA)[2] believe that natural gas will continue to increase its share in global energy, with an annual growth rate of 2.4% until 2018. In another words, the world is entering a golden age of natural gas. Currently, due to the morphological characteristics of natural gas, a unified global natural gas spot market does not exist. According to different price standard, global market is mainly divided into three major regional markets: the North American market, the European market and the Asia-Pacific market. The North American market has gradually become the most mature market of them. It has a competitive market system and its market risk can be controlled by cash and derivatives. Therefore, research on the North American gas market is more representative. The natural gas spot price is a part of the natural gas market, and the North American natural gas spot price always fluctuating immensely. In Fig. 1, the prices have been fluctuating between \$1.7 and \$3.5/MMBTU before 2000. From 2000 to 2010, the extent of short-term changes in price is significant, considering the peaks and valleys. The highest price is \$18.48/MMBTU and the lowest is \$2.06/MMBTU. These prices from 2010 generally stayed below \$5/MMBTU. The high volatility of natural gas prices means that energy producers and distributors are often faced with high volatility risk. Therefore, in order to avoid market risks and improve energy security, it is of great importance to study the characteristics of price fluctuations of the North American natural gas market, which is exemplary to Europe and Asia markets.

Researchers at home and abroad have studied many kinds of price time series, like finance, energy, commodities, etc. For example, Shahmoradi in the process of data generation, studied the heteroscedasticity of natural gas futures prices, using ARCH and GARCH models to analyze time varying returns and volatility of Henry Hub natural gas futures contract market in the New York Mercantile Exchange (NYMEX) [1]. Orlowski investigated the dynamic evolution of price volatility and trading volume of the 10-year US Treasury note futures within the context of transition from pit to electronic trading. The empirical results showed that negative correlation exists between trading volume and price fluctuations, and the shift to electronic trading drives a substantial increase in trading volume, but not in price volatility of Treasury futures [2]. Chen studied the properties of 21 kinds of metal prices in 1900–2007, and found that the effect of the same kind of metal on metal price is much higher than the volatility spillover effect between all kinds of metal, and most of the fluctuations are caused by commodity specific risk rather than macroeconomic factors. Therefore, metal exporters can diversify metal exports to reduce the impact of metal price fluctuations [3]. Kanamura used the SDV model to analyze the volatility of natural gas prices in the US. It is found that there is reverse leverage effect and volatility equilibrium effect in the US natural gas market [4]. Auer tested daily effect in returns and volatility of crude oil using the virtual augmented GARCH model and found that: (1) Volatility on Mondays are much higher than all other weekdays. (2) Returns on Mondays tend to be lower than other weekdays. (3) Results are fairly robust to the choice of other frequently used GARCH model variants, like GARCH-M, TGARCH and CGARCH [5]. Goor analyzed the impact of supply and demand fundamentals to price fluctuations on the British gas market. It was observed that, many types of supply curves and linear supply curve lead to leverage effect through the GARCH-M and EGARCH model. At the same time, they found seasonal fluctuation effect is no longer significant in 2014, which is owing to the wider use of natural gas in power plants and higher liquidity of natural gas spot market [6].

Existing research works on natural gas price fluctuations often use statistical and econometric models to do quantitative analysis. With the development of complex network theory in various subjects, such as cellular networks, protein function networks, neural networks, etc., it has become a new approach to the study of energy. For example, An has studied the relationship between general trading countries through the establishment of a global crude oil trade network model. He found that, the international crude oil trade network is evolving into a stable, orderly and integrated system, and different types of events have different impacts on the import and export countries [7]. This paper adopted a new method—visibility graph algorithm which converts time series to complex network. We built the overall and five local visibility networks of

[1] The data comes from BP Statistical Review of World Energy 2015.

[2] The IEA (International Energy Agency) is an autonomous organization which works to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA has four main areas of focus: energy security, economic development, environmental awareness and engagement worldwide.

Please cite this article in press as: M. Sun, et al., Visibility graph network analysis of natural gas price: The case of North American market, Physica A (2016), http://dx.doi.org/10.1016/j.physa.2016.06.051