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The behaviour mechanism analysis of regional natural gas prices: A multi-scale perspective

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ABSTRACT

This paper analyses the behaviour mechanisms of natural gas prices in North American, Asian and European markets from a multi-scale perspective using the Ensemble Empirical Mode Decomposition and the cross-correlation method. The analytical framework directly measures contributions of the multi-scale components to natural gas price fluctuations and further investigates the dynamic relationships between influential factors (such as crude oil prices, weather and natural gas inventories) and each of multi-scale components of regional natural gas prices. The results show: (1) Emergency events and the short-term disequilibrium between market supply and demand have significant impacts on natural gas prices in North America, while in Japan and Europe, trend terms play a leading role in natural gas price fluctuations. (2) Unlike other markets, the North American natural gas market and the international crude oil market have significant interaction mechanisms. Temperature changes in the winter, rather than in the summer, can cause Henry Hub spot prices to fluctuate. (3) Oil prices play the leading role in affecting Asian and European natural gas prices, having advance effects of one to three months and one to six months, respectively.

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1. Introduction

Currently, natural gas is a kind of clean energy whose ratio in the energy consumption structures for many countries has gradually increased. Due to the uneven distribution of the world's natural gas resources, global natural gas trading activities have continuously increased. It is very important for import countries, related energy policy makers and market players in different regions to grasp the essential features of natural gas price fluctuations and its influencing mechanisms driven by some specific factors. Generally, natural gas prices have been affected by many factors, in which the short-term disequilibrium between market supply and demand, significant events, and the fluctuations of international crude oil prices are likely to cause natural gas prices to fluctuate in varying degrees. At present, the global natural gas market is divided largely into three distinct regional markets. Due to the differences in market maturity, pricing mechanisms, resource endowments and importing sources, natural gas price fluctuation characteristics vary in the three distinct regional markets. At the same time, the fluctuation characteristics of regional natural gas prices at different time scales and the effects of influential factors on multi-scale components of regional natural gas prices may be different. Analysing these variances can help understand the fluctuation features and the risk sources of different regional natural gas markets. By this way, it can help natural gas importing countries develop effective importing strategies to protect natural gas supply security and help natural gas market investors and other market players develop effective investment and market strategies to avoid market risks.

In general, many factors have been considered in the previous studies to disclose the influencing mechanism of natural gas prices. Henning et al. [1] analysed the driving factors of natural gas price fluctuations, focussing on weather, fuel switching, crude oil, the growth of natural gas end-use demand and speculative factors. Serletis and Shahmoradi [2] analysed the determinants of price fluctuations in Henry Hub natural gas futures market, and their results showed that the seasonality and open contracts had a significant impact on natural gas price fluctuations. Mastrangelo [3]

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analysed the fluctuation characteristics of Henry Hub natural gas spot prices, showing that natural gas fluctuations exhibited strong seasonal characteristics. Suenaga et al. [4] analysed NYMEX natural gas futures prices using a partially overlapping time series model, and their results showed that natural gas price fluctuations were strongly tied to seasonal demand and inventories. Brown and Yücel [5] found that, even when various factors were incorporated into the model, crude oil prices still played an important role in determining natural gas prices. Roesser [6] and Arora and Lieskovsky [7] found that natural gas prices were mainly affected by weather, natural gas supply, natural gas inventories, infrastructure constraints, domestic natural gas production, domestic and global demand and other commodity speculation factors. Ji et al. [8] investigated the effects of the increase and decrease of oil prices on regional natural gas prices, and the results indicated the response of natural gas prices to oil prices shows an asymmetrical mechanism. Nick and Thoenes [9] used a structural VAR model to analyse the German natural gas market, and their results showed that natural gas prices were affected mainly by temperature, storage and supply shortfalls in the short term. van Goor and Scholtens [10] and Martínez and Torró [11] found that the price fluctuations in European natural gas market were influenced by seasonality.

Some scholars have also analysed the impact of information announcements regarding natural gas inventories on natural gas price fluctuations. For example, Linn and Zhu [12] found that the release of weekly reports on natural gas inventories had a significant impact on natural gas price fluctuations. Mu [13] found that, on the day on which natural gas inventory reports were released, natural gas price fluctuations were significantly higher, indicating that market fundamentals information had an important impact on natural gas price fluctuations. Chiou-Wei et al. [14] analysed the impact of the weekly natural gas inventory reports released by the US Energy Information Administration on the behaviour of US natural gas futures and spot prices, indicating that market participants relied heavily on fundamental information for the natural gas market. Some academics have also analysed the relationship between natural gas trade and price fluctuations in natural gas futures market, and their results have showed a significant impact of natural gas trade volumes on price fluctuations in natural gas futures market [15,16].

Although most factors have been analysed in the above studies, their impacts on natural gas fluctuations are mainly based on a single time scale. However, it's worth noting that different factors will exert specific influence at different time scales, that is, some factors indeed affect price fluctuations in the short term while other factors may have a long-term influence. In addition, most analyses are limited to North American Henry Hub spot and futures prices, while few researches have analysed and compared the fluctuation characteristics in European and Asian natural gas markets.

As a complement of the previous studies, this paper attempts to answer two questions. First, whether the natural gas prices at different time scales behave the same price characteristics? Second, what are the main differences on the driving mechanisms among North American, European and Asian markets.

Therefore, the following research framework has been constructed. Firstly, an EEMD (Ensemble Empirical Mode Decomposition) method is used to decompose regional natural gas prices into IMFs (intrinsic mode functions). Then, these IMFs are composed by the fine-to-coarse reconstruction algorithm into three multi-scale components of natural gas prices, which indicate specific economic meanings. Next, we further use a cross-correlation method to analyse the dynamic relationships between regional natural gas prices and international crude oil prices at multi-dimensional time scales. At the same time, taking into account the impact of weather and inventories on North American natural gas supply and demand, we also use the cross-correlation method to deeply analyse the impact of these factors on multi-scale components of natural gas prices for the North American market.

Thus, this paper makes two main contributions: (1) It measures the contributions of the multi-scale components to different regional natural gas price fluctuations and unravells the nature of regional natural gas price fluctuations from the multi-scale perspective, and (2) it analyses the dynamic relationships between influential factors and different regional natural gas prices at multi-dimensional time scales, which can help understand the complex interaction mechanism between regional natural gas markets and crude oil markets and distinguish the effects of the other influential factors on regional natural gas prices.

The rest of this study is organized as follows. Section 2 briefly describes the methods and the data source. The results and discussion are presented in Section 3. Finally, major conclusions are drawn in Section 4.

2. Method and data source

Scientifically removing fluctuation signals from the price curve is still an on-going issue in the research field. Using the EEMD and the fine-to-coarse algorithm, we can obtain three multi-scale components clearly and define them as specific fluctuation modes with corresponding economic meanings. And the cross-correlation method helps analyse the influencing mechanisms for regional natural gas prices.

2.1. Ensemble Empirical Mode Decomposition

EEMD is a proposed improvement of the EMD (Empirical Mode Decomposition) method. EMD was developed by Huang et al. [17] as a generally nonlinear, non-stationary data processing method. The method can decompose natural gas price series into independent IMFs, which can facilitate the analysis of natural gas price fluctuations at different time scales. Currently, in the social science literature, some studies have achieved good results using the EMD method to analyse problems related to financial time series, international crude oil prices, etc [18–22].

The EMD method assumes that the data may have many different coexisting modes of oscillations at the same time, as well as simultaneous fluctuation patterns at different time scales, which can be extracted from the original price series. However, the EMD method has a drawback: different modes are often mixed. To overcome this problem, Wu and Huang [23] proposed the EEMD method on the basis of the EMD method, adding white noise to the original time series to help extract the true signal in the data and then decomposing the improved time series.

The procedure of the EEMD method is developed as follows:

i) Firstly, adding a white noise series to the targeted data $x(t)$, we get the new data $X(t)$. We use the cubic spline function to fit the local maxima and local minima of the new data series to get the upper envelope $e_{\max}(t)$ and the lower envelope $e_{\min}(t)$. Then, we calculate the mean a_1 from the upper and lower envelopes.

$$a_1 = [e_{\max}(t) + e_{\min}(t)]/2 \tag{1}$$

ii) Next, we extract the mean from the time series $X(t)$ and define the difference between $X(t)$ and a_1 as f_1:

$$f_1 = X(t) - a_1 \tag{2}$$

In general, here f_1 is not the IMF (intrinsic mode function). Thus, we should repeat step 1 iteratively, but with different white noise

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