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The spillover effects across natural gas and oil markets: Based on the VEC–MGARCH framework

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HIGHLIGHTS

- This paper proposes a VEC–MGARCH framework for examining spillover effects in price and volatility.
- This paper takes into consideration of regional segmentation and different pricing mechanism of natural gas.
- This paper compares the difference of spillover across US, Europe and Japan.
- This paper investigates hedging and risk management based on spillover effects.

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ABSTRACT

This paper empirically investigates both price and volatility spillover effects in a comprehensive VEC–MGARCH framework. The hedging strategy is further discussed using the spillover effects. Crude oil and natural gas markets of US, Europe and Japan are examined for regional segmentation and different pricing mechanisms of natural gas. Our results show that the European and Japanese gas prices are cointegrated with Brent oil prices, but US gas price is decoupled from oil due to natural gas market liberalization and shale gas expansion. In all cases, the results support the presence of price spillover from crude oil markets to natural gas markets, but a reverse relationship does not exist. The asymmetric price spillover effects might be explained by the relative size of each market. It was also found that the volatility in oil market seems to spillover to the natural gas market, and vice versa, in both US and Europe. On the contrary, volatility seems to be independent in natural gas and oil markets in Japan. The difference in the results of the volatility spillover effects could be explained by the pricing mechanism of natural gas, especially the risk avoidance mechanism in gas pricing in Japan. The risk management performance of hedging strategy is remarkable considering volatility spillover.

1. Introduction

Recent turmoil in energy markets has generated interests in studying the spillover effects across different energy sectors. Two stylized facts about energy markets are that prices in different energy sectors tend to be linked [1,2], and their volatilities seem to be transmitted from one market to another [3]. The first of the stylized facts is often regarded as the evidence of energy markets integration and price spillover effect. Numerous methods have been applied to investigate markets integration and price spillover effect. Of these methods, cointegration analysis and vector error correction (VEC) model proposed by Engle and Granger [4] are by far the most popular methods. The second stylized fact is usually taken as volatility spillover effect. Co-volatility is the manifestation of cross markets hedging and changes in common underlying information, which might shift expectations across markets simultaneously [5]. According to Malik and Hammoudeh [6], multivariate generalized autoregressive conditional heteroscedasticity (MGARCH) developed by Bollerslev et al. [7] has been widely used for analyzing volatility and correlation spillover effects across sectors.

This paper investigates the spillover effects between oil markets and natural gas markets in a comprehensive framework, including both price spillover and volatility spillover. Investigating whether price and volatility in one market transmit into another market is of great practical importance. For price spillover, it affects the

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necessity of natural gas market liberalization. Important assumptions for supporting the liberalization of natural gas market is that the price linkage between natural gas and crude oil would be mitigated in a fully liberalized gas market; and gas price might decrease significantly after the linkage mitigation [8]. This is helpful to consumers. Therefore, it is necessary to examine whether natural gas and crude oil prices are related in different regions with different natural gas pricing mechanisms, and whether price changes in one market would spillover to the other. For volatility spillover, volatility is usually regarded as a proxy for information flow [9], which might be important for market participants. It is necessary to investigate how volatility and information flow between markets. Since there are close informational connections across energy sectors, financial market participants can use these linkages to find optimal hedging positions and thus reduce uncertainty.

We propose the empirical analysis of spillover effects for three main regional natural gas markets that are geographically segmented: US, Europe and Japan. There are two reasons for choosing the three gas markets. First, unlike the global crude oil market, natural gas markets tend to be geographically segmented [10], gas prices and their historical trends usually appeared to move separately of each other. And these three regions basically involve the main markets of natural gas. On the other hand, the pricing mechanisms of natural gas in US, Europe[1] and Japan are different, which is meaningful for investigating the spillover effects under different pricing mechanisms.

The contributions of this paper are as follows. First, we propose a comprehensive framework for examining spillover effects in price and volatility by combining VEC and MGARCH techniques. This is the first attempt at using this to study energy markets. Second, taking into consideration regional segmentation and different pricing mechanism of natural gas, a comparison of US, Europe and Japan is undertaken to investigate whether the price and volatility spillover effects are similar or unique across the three regions. Third, the effectiveness of hedging strategy is discussed considering the spillover of volatility. To the best of our knowledge, the present paper fills a gap in the energy markets literatures as it provides a comprehensive framework for investigating price and volatility spillover effects, and compares the difference in spillover across different regional natural gas markets with different degree of market liberalization and different pricing mechanism.

The main findings of this paper could be summarized as follows:

1. Natural gas price in the US is decoupled with crude oil price in the long term due to gas market liberalization, soaring supply of shale gas and limitation of liquefying and export capacity.
2. The price change in crude oil market would transmit to the gas market in all the three regions as natural gas and oil are seen as substitutes in consumption and complements and rivals in production. But there is no indication of price spillover from natural gas to oil. The relative size of each market might be the reason for the asymmetric relationship.
3. The volatility in oil market seems to spillover to natural gas market, and vice versa, in both the US and Europe. On the contrary, the volatility in Japan seems to be independent between natural gas and oil markets. Hedging strategy is effective while considering volatility spillover by remarkably declining portfolio variances.

[1] In this study, Europe refers to Continental Europe because the pricing mechanism in UK is different with Continental Europe, and UK's natural gas market is relatively independent with Continental Europe. Similar to the US, natural gas market of the UK was liberalized.

The remainder of the paper is organized as follows. Section 2 briefly presents an overview of studies investigating the linkage in different energy prices, both within and between natural gas and oil markets. In Section 3, the data set used in this paper is described and preliminary analysis of the time series is undertaken. Section 4 discusses the model specification, in which we combined the VEC and MGARCH techniques into a framework. The empirical results are discussed in Section 5. The final section is the conclusion.

2. Literature review

The spillover between markets has been the subjects of intensive studies and interest in the topic has been growing over years. Due to the large literature on the subject, we cannot review these studies one by one. Thus, relevant studies on spillover are summarized in Table 1. As can be observed from Table 1, most studies test spillover (either returns or volatilities) among different stock markets or between the crude oil market and financial markets. Several empirical approaches have been applied in this literature, among which MGARCH is one of the most widely used method.

When it comes specifically to the relationship among different energy prices, both within and between natural gas and oil markets, it is necessary to provide a brief review of these studies for underlining our contributions. Given the increasing importance of natural gas as a source of clean energy and the geographical segmentation of natural gas markets, several literatures try to evaluate the market integration of natural gas. Numerous researches, such as De Vany and Walls [32] and Cuddington and Wang [33] for US natural gas markets, Asche et al. [34] and Neumann et al. [35] for European markets, have focused on market integration from regional perspective. They all find that natural gas markets at the regional level have been progressively integrated. With the increase in liquefied natural gas (LNG) trade, the global integration of segmented markets in Europe, North America and Asia have been accelerated [36]. Siliverstovs et al. [37] focused on natural gas market integration in Europe, North America and Japan from a global perspective using the principal components analysis and cointegration procedure. The results show a highly integrated natural gas markets within North America and within Europe, as well as the regional markets between Europe and Japan. They further find that North America markets are neither integrated with Europe or Japan.

Apart from integration within natural gas markets, the linkage between natural gas and oil has also sparked renewed interest given that crude oil and natural gas are substitutes in consumption and complements and rivals in production [10]. Villar and Joutz [10] examine the relationship between the West Texas Intermediate (WTI) crude oil price and Henry Hub natural gas price, and they find that the prices of crude oil and natural gas have had a stable equilibrium relationship historically, although there are some periods where they appeared to be decoupled. In order to examine whether oil and natural gas prices in UK 'decoupled' after gas market liberalization, Panagiotidis and Rutledge [8] investigate the relationship between the Brent oil price and UK wholesale natural gas prices. Their results do not support the assumption that gas prices have decoupled with oil prices. Similarly, Erdős [2] applies VEC models to study the price spillover between oil and natural gas in Europe, Asia and US.

Given the literature on spillover effects within and between energy markets, there are three issues that need to be addressed. First, most empirical researches pay attention to price spillover effects, while ignoring volatility spillovers. Until now, most studies on volatility spillover in energy markets, including Malik and Hammoudeh [6], Soytas and Oran [38] and Arouri et al. [39], have