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The U.S. shale gas revolution and its effect on international gas markets

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ABSTRACT

The U.S. natural gas price dropped dramatically in the U.S. after the shale gas revolution. This paper investigated if the change in the structure of the U.S. natural gas market after the revolution is affecting the Japanese and European gas markets. We used the Bai–Perron test to identify the break date related to the shale gas revolution and tested if the market linkages among the U.S., Japanese, and European gas markets changed before and after the statistically determined break date. The result indicated that the U.S. gas market had a price relationship with the international markets for the period before the break date related to the shale gas revolution, but this relationship disappeared for the period after the break date. This result implied that the U.S. gas market became independent after the shale gas revolution and that the price linkage between the U.S. and international gas markets became weaker after the shale gas revolution. The study revealed that the effect of the U.S. shale gas revolution is not yet affecting the international gas markets.

Introduction

The development in new technology for shale gas drilling increased shale gas production in the U.S. from 1% to 20% between 2000 and 2010. It is believed that this increased gas production has caused a downward pressure on gas prices worldwide (Stevens, 2012). This dramatic movement in the U.S. gas market, which is said to have begun in late 2005, is now known as the 'shale gas revolution' (McGregor, 2012). The U.S. Department of Energy estimates that the total unproved technically recoverable shale gas has more than quadrupled since 2006 to 482 trillion cubic feet at the end of 2011 (EIA, 2012). As the amount of extractable natural gas is increasing in the U.S., the U.S. will likely start to expand fracking to export shale gas to other countries. However, infrastructure such as the new liquefaction facilities and other technologies to liquefy natural gas is still limited at the moment, and it may take several years before the U.S. to export its shale gas to other countries. Thus, although the shale gas revolution has dropped the price of natural gas in the U.S. market, it could be that the effect of the U.S. gas market on the international gas market is still limited within the North American continent at this stage. If so, it might be that the impact of the U.S. shale gas revolution has not yet spread out to countries with a large natural gas demand that are not connected to the U.S. with gas pipelines like Japan and Germany.

The objective of this paper is to elucidate this issue by determining if the price drop in the U.S. gas market due to the increased U.S. shale gas production is affecting the linkages among the U.S. and international gas markets. For this purpose, we test if the market relationships among the U.S., Japanese, and European natural gas markets changed before and after the shale gas revolution. We identify in this study if the effects of the current phenomenon of shale gas revolution in the U.S. are spreading out globally and find out if this revolution is affecting the Japanese and European gas markets. This is important issue to be examined because examining whether the U.S. shale gas revolution is already influencing the global gas markets would provide helpful information for policy makers of countries that are seeking ways to secure their energy supply. Furthermore, this study will be useful for understanding what influence may occur in the global gas and oil markets when similar technological change in unconventional gas and oil drilling occurs in some countries in the future.

Although many studies have investigated the integration of natural gas markets among different gas markets (Serletis and Herbert, 1999; Asche et al., 2002), most of these studies are limited to the regional level, such as within North America or Europe. To analyze market integration among international gas markets, Siliverstovs et al. (2005) tested the long-run market relationships among the North American, European, and Japanese natural gas markets. Their study indicated that the U.S. market is not integrated with the European and Japanese gas markets and that the European and Japanese markets are somewhat integrated. However, the period used for that study was 1993:11–2004:3, which

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is the period before the shale gas revolution is said to have taken place in the U.S. Furthermore, although it is becoming important to consider the effects of structural breaks when investigating the market relationships for the international gas markets, most of the previous studies do not incorporated such effects in their test models. Our study will not only update and configure the market relationships among the international gas markets by using the latest data but also consider the structural breaks in the test model and identify how such breaks will affect the relationships among the international gas markets.

For a relevant study, Wakamatsu and Aruga (2013) investigated how the U.S. and Japanese gas markets were affected by the shale gas revolution and found that the U.S. gas market became more independent from the Japanese market after 2005. Their paper suggests that this change is related to the shale gas revolution. However, their paper only investigated the consumption linkages and did not test the effect of revolution on the price linkages. Furthermore, the focus of Wakamatsu and Aruga (2013) was on whether the U.S. gas demand structure became independent from that of Japan. On the other hand, the interest of this study is to find out whether the U.S. shale gas revolution has influence on the global gas markets. Thus, this paper will include the European gas market in addition to the Japanese market and examine how the price linkages between the U.S. and two large international gas markets are affected after the shale gas revolution.

Investing price linkages is important and different from consumption linkages because market price reflects both the demand and supply behaviors so that we can identify if the law of one price (LOP) holds among the international gas markets.[1] As suggested by Stigler and Sherwin (1985) the price based approach is preferable when investing market integration among different regional markets. Thus, we will apply this price based approach to investigate how market linkages between the U.S. and international gas markets are affected by the shale gas revolution. In this sense, this is the first study to identify if the dramatic increase in the shale gas production in the U.S. around the mid-2000s is influencing the level of market integration between the U.S. and international gas markets.

The paper consists of two parts. In the first part, we statistically identify the break date using the U.S. natural gas marketed production time series data.[2] Although it is claimed that the shale gas revolution occurred in the mid-2000s, no agreement exists in the U.S. regarding when exactly it happened. Hence, we assume that the statistically identified break point around the mid-2000s in the U.S. marketed production time series is the point at which the revolution began. In the second part of the paper, we split the U.S., Japanese, and European natural gas price series using the break point discovered in the first part and test how the price relationships among these three natural gas markets change.

We expect that the price relationships among the three countries will not change if the U.S. gas market continues to move together with the international markets even after the shale gas revolution occurred. If this is the case, the price drop in the U.S. gas market will have a direct impact on the international gas markets so that the prices of the international gas markets will drop with the U.S. gas price. This phenomenon will occur if the international gas markets respond quickly after the U.S. increases its gas production through the new technology for shale gas drilling. There are two possible reasons for the international gas markets to be affected by the U.S. shale gas revolution. First, if the U.S. export of natural gas increases after the shale gas revolution, the structure of the international gas supply will be affected, and hence, the gas price in the exporting countries will drop accordingly. Second, as the U.S. starts to use its own natural gas after the revolution, the amount of natural gas imported to the U.S. will decrease. If so, and if this amount is large, the demand structure of the international gas market can be affected.

However, if the price linkage between the U.S. and the international gas markets disappears after the break point, it is probable that the shale gas revolution only changed the structure of the U.S. gas market. It would mean that the above mentioned causes from the U.S. shale gas revolution that could affect the international markets are not occurring at the moment and that the impact of the revolution is not yet affecting the international gas markets.

In the following section, we discuss the methods used to identify the break date for the shale gas revolution and explain the methods we used to examine the effects of the revolution on the international gas markets. In the third section, we show the results of the econometric analysis. Finally, in the last section, we present the conclusion drawn from this study.

Methods

We use the Bai–Perron (BP) method (Bai and Perron, 1998) to statistically determine the break points in the production data. This method is useful when the break point is unknown and when the time series data contain more than one break point (Aruga and Managi, 2011). The statistical model used in the BP test is based on the following multiple regression models with m breaks:

$$y_t = x_t'\beta_j + u_t \; (t = T_j - 1 + 1, \ldots, T_j \; j = 1, \ldots, m+1) \quad (1)$$

where y_t is the dependent variable at time $t(t = 1, \ldots, T)$, x_t is the vector of regressors, β_j is the corresponding vector of regression coefficients, and by convention, $T_0 = 0$ and $T_{m+1} = T$. The BP test uses the maximum F-statistic that is calculated from the global minimum of the sum of squared residuals obtained from Eq. (1) to statistically identify the number of appropriate breaks in the time series data by applying F tests for 0 vs. l breaks and l vs. $l + 1$ breaks (see Bai and Perron, 1998). The maximum number of breaks m is set to 2 in our model because the recursive estimates test (Ploberger et al., 1989) and F statistics test (Andrews, 1993) suggested that $m = 2$ is the favored model compared with other models. After setting m to 2, the statistically optimal number of breaks was identified when the residual sum of squares (RSS) and the Bayesian information criterion (BIC) became the smallest (see Zeileis et al., 2003).

Because we think that the effect of the U.S. shale gas revolution would be the most apparent in the natural gas withdrawal data, we use the natural log of the U.S. natural gas marketed production (million cubic feet) data to identify the break point. The data are obtained from the U.S. Energy Information Administration (EIA), and the length of the series we used is the 1992:1–2012:10 period. Fig. 1 shows that the U.S. natural gas marketed production has an increasing trend after the drop in production related to Hurricane Katrina in September 2005. It is evident that this increasing trend after late 2005 is strongly related to the shale gas revolution.

We expect that the BP test will identify a break point other than the one found around the mid-2000s. If we find the other such break, we create an exogenous dummy variable based on this break points We then incorporate the effect of this break by including it in the cointegration model as an exogenous dummy variable. The dummy variable takes the value of 1 for periods after the break date and takes the value of 0 for periods before the break date.

[1] The LOP is an economic theory that states that in an efficient market prices of identical goods sold at different markets should converge to one price due to arbitrageurs (Li et al., 2010). Existence of price linkage among different markets is one of the important indicators for having LOP to hold among different markets.

[2] The "break date" in this paper is the break period statistically identified by the Bai–Perron test. Please see Bai and Perron (1998) for details of the definition.