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Oil indexation, market fundamentals, and natural gas prices: An investigation of the Asian premium in natural gas trade

Dayong Zhang[1], Min Shi[1,3], and Xunpeng Shi[2,3*]

1: Southwestern University of Finance and Economics, China;
2: Australia-China Relations Institute, University of Technology Sydney, Australia;
3. Energy Studies Institute, National University of Singapore, Singapore.
*Corresponding author: Xunpeng Shi, Email: xunpeng.shi@gmail.com; Tel. +61 431 002760.

Abstract

A heated debate has arisen over whether the Asian premium (i.e., higher prices in Asia than elsewhere) in natural gas trade is due to price discrimination or market fundamentals. Determining the origin of this premium can help to guide the gas industries and policy makers in Asia, especially when the traditional oil-indexed price mechanism fades away. Using a new systemic time-series approach, this paper explores the extent to which oil prices and market fundamentals contribute to variations in gas prices in Japan, the United States, and Germany. We find clear cross-country differences and time-varying patterns. Gas prices are much less affected by supply and demand factors than oil prices in Japan and Germany, whereas these factors are more important than oil prices in the US market, which has a pricing hub. Through rolling-windows and subsample analysis, we discover that oil prices were important in Japan and Germany, but the level of importance has declined significantly in recent years, though the contribution of fundamentals does not change much. The results show that Asian gas prices are determined more by oil prices than by the market fundamentals; thus the Asian premium is more likely due to this oil indexed pricing mechanism, rather than market fundamentals. This suggests that developing Asia's benchmark prices (through trading hubs) with a better reflection of regional specific fundamentals can lead to a more efficient allocation of gas resources.

JEL: Q31, Q41
Keywords: Asian premium; gas price; oil indexation; systemic approach; variance decomposition

1. Introduction

The concept of an “Asian premium,” which originated in crude oil markets, has been extended to the natural gas market. Specifically, it refers to a higher level of gas prices in the Asian market than in the US and European markets. It is particularly common in the era that followed the global financial crisis (GFC) in 2008, when prices for liquefied natural gas (LNG) became significantly higher in Asia than gas prices in the other two markets. Motivated by the Asian premium and the development of hub-indexed pricing in the United States and Europe, East Asia is gearing up to change its dominant oil indexation in its long-term contracts to more flexible, hub-indexed prices for LNG and gas imports (Shi and Variam, 2016).

However, whether higher gas prices in Asia are due to pricing discrimination or simply reflect differences in the market fundamentals (defined as supply and demand factors) is still debated in both academia and the gas industry. Natural gas does not have a global market (Bachmeier and Griffin, 2006); rather, it has two major trading markets other than the one in Asia: the North American and European markets. Thus prices and pricing mechanisms vary across regions, as do the market-specific features of these markets. US gas prices are set through gas-on-gas competition in the Henry Hub, whereas European gas prices are mixed-hub prices from the UK’s National Balancing Point (NBP) and the Dutch Title Transfer Facility (TTF) as well as indexation to oil prices. Gas prices in Asia are usually indexed to the Japanese Customs-Cleared (JCC) oil price, the Brent oil price, or the official Indonesian Crude Price. Oil indexation exogenously sets gas prices and thus differentiates East Asian gas economies from standard market economies (Shi and Variam, 2017). Commercial arrangements, such as destination clauses, further limit arbitrage opportunities in natural gas markets (Shi and Variam, 2016). Therefore, prices on the three markets may not be comparable.

The fundamental driving forces behind international natural gas prices are more complicated (Stern, 2014) and might change over time and across markets. Yet few studies have tried to identify the major driving factors, and related quantitative studies are extremely scarce. It is critical for policy debates and academic literature to understand the fundamentals of the natural gas market and how much they contribute to natural gas pricing. This is because if the market fundamentals are the determining factors of natural gas prices in East Asia, moving away from oil indexation may not be the solution to the Asian premium.

This paper therefore aims to fill the gap and examines the determinants of natural gas prices through a systemic time-series approach. It also sheds lights on the causes of the Asian premium through a cross-country comparison. Using historical data from three countries—Japan, the United States, and Germany—we hope to reveal the role that various factors—supply, demand, global economic conditions, and the oil market—play in natural gas price variation and how their roles change over time.

The contribution of this paper can be summarized in the following four key points. First, to the best of our knowledge, this is the first paper to quantitatively analyze the Asian premium argument in the natural gas sector and thus makes a contribution to the policy debate on the cause of the Asian premium. The results show clearly that East Asian gas prices are not mainly determined by market fundamentals, and thus market fundamentals are not the cause of the premium. Second, a recently developed time-series approach proposed by Diebold and Yilmaz (2009, 2014) is adopted for the first time to investigate factors that potentially influence natural gas prices. The method is essentially based on the vector autoregressive (VAR) model and the variance decomposition method. It allows all variables to be endogenous and fits them into a system. By repackaging variance decomposition results, it enables us to find out how much natural gas price variation is affected by the dynamics of other factors. Third, the systemic approach allows us to model a range of macroeconomic factors simultaneously. The fourth contribution is in allowing time-varying features in the system, using a rolling-windows approach and with further division of the sample into two periods, which reflects the clear structural changes after the 2008 GFC.

The remainder of this paper is organized as follows. Section 2 reviews the previous literature. Section 3 briefly describes the methodology. Section 4 discusses the data. Section 5 reports and discusses our empirical results, and section 6 concludes with policy implications.

2. Literature review

The Asian premium in the gas sector has been debated in both academia and the gas industry, generated by a real policy issue over whether to retain the oil-indexed gas pricing mechanism. Until the 1990s this mechanism was effective, but recently it has come under criticism (Stern, 2014; Vivoda, 2014). Opponents of oil indexation argue that oil indexation ignores fundamental factors in the natural gas market and is no longer appropriate (Stern, 2014). In the twenty-first century, as oil and gas are no longer the main substitutes in the end-user market, it is no longer appropriate to index gas prices to oil (IEA, 2014). Especially since the recent shale gas revolution and the Fukushima nuclear power plant accident in Japan in 2011, the relationship between gas and oil prices has been significantly affected (Geng et al., 2016a, 2016b, 2016c; Ji et al., 2014).

Many studies observe that natural gas prices used to link to oil prices but decoupled recently, and they were much more volatile than oil prices (Geng et al., 2016b; Serletis and Shahmoradi, 2005). Since then, papers have emerged that question the long-term equilibrium relationship between crude oil and natural gas prices. Hartley et al. (2008) find short-run departures from the long-run equilibrium between crude oil prices and natural gas prices. Seasonal factors—such as inventory, weather, and supply shocks—are the main reasons for this short-term decoupling. Erdős (2012) investigates natural gas prices with crude oil prices in the United States and the UK and finds decoupling around 2009. He also points out that natural gas prices in the United States and the UK appear to be separate from each other. Ramberg and Parsons (2012) conclude that the co-integrating relationship between natural gas and crude oil prices is not stable over time, and the two prices are tied to each other weakly, as shown by the large range of confidence intervals. Also, they observe that the relationship can shift dramatically over time. Lin and Li (2015) testify to the spillover effect between crude oil and natural gas markets in the United States, Europe, and Japan using first (mean value) and second (volatility) moments.

They find that crude oil and natural gas prices are co-integrated in Europe and Japan but decoupled in the United States. Also, they indicate that the price spillover direction is from crude oil to natural gas, not vice versa. Several studies show that a structural break in the relationship between oil and natural gas prices was affected by the development of shale gas (Caporin and Fontini, 2017; Geng et al., 2016b; Wakamatsu and Aruga, 2013), and the Fukushima nuclear accident led to more LNG imports to Japan and increasing investment in LNG projects worldwide (Hayashi and Hughes, 2013a, 2013b).

Many other studies, however, support oil indexation. For example, some studies find that crude oil and natural gas prices have a cointegration relationship in the long run. Villar and Joutz (2006) find a relationship of cointegration between Henry Hub natural gas prices and West Texas Intermediate (WTI) crude oil prices. Asche et al. (2006) test for market integration between natural gas and other energy sources, such as crude oil and electricity, in the UK. Using two reforms in the natural gas market as natural experiments, they find that a single energy market exists in the UK, which means that the integration relationship holds. Furthermore, they conclude that the crude oil price is the driving price. Panagiotidis and Rutledge (2007) examine the relationship between wholesale gas prices in UK and the Brent oil price. They find that a constant cointegrating relationship exists in both the long run and the short run, thus the decoupling assumption is not supported. Asche et al. (2013) see that European continental contracted gas prices are driven by oil prices as well, and the new spot markets in Europe also follow the same process of price determination as the

UK gas market, hence all spot prices are determined by oil prices in the long run. Brigida (2014) allows multiple regimes when studying the cointegrating relationship between natural gas and crude oil prices. He finds that a regime-switching mechanism exists, but the prices of oil and gas are still cointegrated, and they faced a temporary shift, rather than permanent decoupling, in the early 2000s.

In order to replace oil indexation, the International Energy Agency (IEA 2013, 2014) and many researchers (Shi and Variam, 2016, 2017; Shi et al., 2016; Stern, 2014, 2016; Tong et al., 2014) call for the creation of East Asian gas trading hubs to generate benchmark prices to reflect East Asia's own regional market fundamentals as an alternative to oil indexation. Shi and Variam (2016) and Stern (2016) both encourage cooperation among Asian consumers to help in the transition to hub pricing.

The Asian premium is often cited as justification for the transition and is a controversial topic. Many gas buyers and academicians argue that oil indexation caused the Asian premium and propose the development of local benchmark prices through trading hubs to replace oil indexation and mitigate the Asian premium (IEA, 2014; Tong et al., 2014). The supporters of using oil indexation for pricing gas, however, argue that the Asian premium is due to different market fundamentals (Blank, 2007;Neumann and Von Hirschhausen, 2015). Past experience also suggests that market fundamentals may vary among the three markets. Although the United States has experienced a shale gas revolution, and Europe has reduced its demand for gas, East Asian countries, such as Japan and China, have increased their need for natural gas. Japan's higher demand results in part from the Fukushima nuclear accident in 2011, and China needs more natural gas because of strong economic growth and increasing pressure to move to more environmentally friendly sources of energy (IEA, 2013). Infrastructure and contractual practices limit the opportunities for arbitrage among regions and thus reduce price divergence across markets. The shortage of sufficient LNG-related infrastructure in the United States makes its gas market relatively isolated from that of the rest of the world. Although LNG trade between the United States and other countries exists, it is not enough to eliminate the price difference between the United States and Asia or Europe.

The IEA considers that the arguments of both parties have merit but prefers the establishment of trading hubs for East Asia's own benchmark prices. The IEA (2014) summarizes the potential reasons for the Asian premium as follows: oil-linked pricing in long-term contracts, the need for security of supplies, a low level of demand flexibility, and the lack of regional trading hubs. Furthermore, Shi and Variam (2016) confirm that destination restrictions that are used to secure LNG supplies made no contribution to the Asian premium.

One key question in the debate on the Asian premium is that whether it represents price discrimination or simply reflects differences in fundamentals among different markets. Some recent work has tried to explicitly identify which factors affect natural gas prices. In other words, are fundamental factors, such as demand and supply, important in determining gas prices? If so, how much do they contribute to natural gas pricing, in isolation from oil prices? Brown and Yücel (2008) assume that natural gas prices are relatively independent of crude oil prices. Therefore, they construct a time-series model to study the drivers of natural gas prices and conclude that weather, seasonality, storage, and production disruptions can explain natural gas prices well. Mu (2007) studies the mean value and volatility of natural gas future returns in the US market. He finds that the volatility of gas prices has a “Monday effect” and a “storage announcement effect,” meaning that the price is high on Monday, when the storage of natural gas is reported. And this is driven by the weather factor, indicating the important role of market fundamentals.

Nick and Thoenes (2014) investigate the driving factors behind gas prices in Germany and find that temperature, storage, and supply shortfalls can have impacts on natural gas prices in the short run; however, in the long run, crude oil and coal prices are still the main drivers. Ji et al. (2014) examine the regional pricing mechanism in the North American, European, and Asian markets. They find that the global economy is the main driving factor in natural gas prices in North America while oil prices play a major part in determining gas prices in Asia and Europe. Giziene and Zalgiryte (2015) use data from the European Union and Lithuania to analyze the structure of natural gas pricing and conclude that both the prices of other forms of energy and fuel (defined as external indicators) and the prices of purchase, storage, transportation, production, and infrastructure cost factors (defined as internal indicators) can affect natural gas prices. Hulshof et al. (2016) investigate the impact of oil/coal and supply and demand fundamentals on the day-ahead spot price on the TTF. They conclude that gas prices are decided through gas-on-gas competition because fundamental factors—such as gas consumption, temperature, and economic activity—have significant impacts on day-ahead gas prices, whereas oil's role is minor, and coal prices have no effect on gas prices.

Geng et al. (2016a) investigate the dynamics of natural gas prices in the United States, Japan, and Europe. They find that oil prices are the dominant determinants in Japan and Europe and supply-demand are the key driving factors in the United States. Examining the US shale gas revolution, Geng et al. (2016b, 2016c) study the role of shale gas on the price movement regimes and the relationship between oil prices and gas prices in the US and European markets. They conclude that the shale gas revolution has a significant impact on US Henry Hub prices, but its impact on NBP prices is limited.

One noteworthy factor that affects natural gas prices is financial markets, especially after 2008. Cheng and Xiong (2013) review studies focusing on the impact of financialization on commodity markets, including the energy market, and conclude that financialization can affect commodity markets through risk sharing and information discovery. Creti et al. (2013) study the correlation between price returns for commodities and the stock market, especially in energy commodities, and they find that this correlation evolves over time and is highly volatile. Also, they indicate that the relationship depends on whether the stock market is bearish or bullish and emphasize the role of the 2008 financial crisis, highlighting the financialization of commodity markets. Creti and Nguyen (2015), however, acknowledge that financial investment influences energy prices but indicate that this impact is perhaps a short-term shock and supply-demand fundamentals still dominate the pricing mechanisms. Zhang (2017) shows that oil prices have become more dependent on the international financial market since the GFC.

Apart from research related to the pricing mechanism and driving factors, some studies focus on market integration, specifically, in North America, Europe, and Asia. Siliverstovs et al. (2005), for example, investigate whether natural gas markets in Europe, North American, and Japan experienced integration during 1990-2004. They find that natural gas markets in Europe and North America are highly integrated. Also, natural gas prices in European and Japanese markets are integrated, but integration among trans-Atlantic gas markets did not occur until the end of the sample period. Following their research, Neumann (2009) considers the role of LNG and studies the integration of the trans-Atlantic natural gas markets based on the law of one price. She examines natural gas prices in North America and Europe and finds an increasing convergence of spot prices on both sides of the Atlantic. Li et al. (2014) find that North American prices are clearly distinct from prices in other markets. They suggest that the integration of Asian and European prices is mainly due to oil indexation.

Although the Asian premium has been clear in the oil markets, no consensus has been reached on the drivers of the Asian premium in natural gas prices. The previous studies on the driving factors behind gas prices focus mostly on markets other than those in East Asia. This paper tries to fill this gap by revealing the driving factors behind gas pricing in East Asia (represented by Japan) and the other two major markets (the United States and Europe).

3. Methodology

Following the literature, this paper constructs a system based on the VAR approach introduced by Diebold and Yilmaz (2009). The system incorporates the supply side, the demand side, oil prices, and global economic conditions in the empirical model and shows how much these factors contribute to natural gas prices. Moreover, we apply this in three major markets—namely, Japan, the United States, and Germany (representing the European market)—to make cross-country comparison in three regions that employ different pricing mechanisms.

The VAR model (introduced in Sims [1980]) is often used to investigate dynamic relations in a system and has been a very useful tool in macroeconomic studies since its appearance. The main advantage of this model is that no prior assumption on exogeneity is needed, and all variables are considered endogenous. However, its results are hard to interpret. To overcome the main disadvantage, Diebold and Yilmaz (2009) propose a simple method of interpreting VAR results based on forecasting error variance decomposition. Repackaging the decomposition matrix enables us to identify not only the connectedness within a system but also the pairwise contributions within the system. The method is then refined by Diebold and Yilmaz (2012) to accommodate the ordering issue of VAR estimation. Diebold and Yilmaz (2014) further suggest using network typology to show the system connections graphically.

The first step in this approach is to estimate a K-variable VAR(p) model and then use H-period-ahead forecasting error variance decomposition to capture how variables within a system are connected to one another. Consider a VAR model of the following form:

$$y_t = \sum_{i=1}^{p} \phi_i y_{t-i} + \varepsilon_t \tag{1}$$

where $\varepsilon_t \sim (0, \Sigma)$ is a vector of independently identically distributed disturbances, and ϕs are matrices of coefficients to be estimated.

Following Hamilton (1994, chapter. 10), a covariance stationary VAR model can be rewritten in an infinite order vector moving average (VMA) form: $y_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i}$, where A_i is the $K \times K$ coefficient matrix and obeys the recursion $A_i = \phi_1 A_{i-1} + \phi_2 A_{i-2} + \cdots + \phi_p A_{i-p}$.

Calculating variance decompositions requires orthogonal innovations, but the typical Cholesky factorization used by Diebold and Yilmaz (2009) is sensitive to the ordering of VAR. To avoid this problem, the generalized approach by Koop et al. (1996) and Pesaran and Shin (1998) can be used. We define the H-period-ahead forecasting error variance decomposition matrix as Θ_{ij}^H, in which θ_{ij}^H is defined as follows:

$$\theta_{ij}^H = \frac{\sigma^{-1}{}_{jj} \sum_{h=0}^{H-1} (e'_i \mathrm{A}_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e'_i \mathrm{A}_h \Sigma A_h' e_j)} \tag{2}$$

where σ_{jj} is the standard deviation of the error term for the j^{th} equation, and e_i is a vector equals to one for the i^{th} element and zero otherwise. Each entry in the variance decomposition matrix is normalized by the row sum as:

$$\tilde{\theta}_{ij}^{H} = \frac{\theta_{ij}^{H}}{\sum_{j=1}^{K}\theta_{ij}^{H}}. \tag{3}$$

After normalization, we have $\sum_{j=1}^{K}\tilde{\theta}_{ij}^{H} = 1$ and $\sum_{i,j=1}^{K}\tilde{\theta}_{ij}^{H} = K$. The H-period-ahead forecasting error variance decomposition results are summarized in Table 1. Each element $\tilde{\theta}_{ij}^{H}$ shows how much (in percentage) variable j explains the variation of variable i.

(Insert Table 1 about here)

The pairwise directional connectedness from j to i can be written as $C^{H}{}_{i\leftarrow j} = \tilde{\theta}_{ij}{}^{H}$, and net pairwise directional connectedness is then calculated as $NC^{H}{}_{ij} = C^{H}{}_{i\leftarrow j} - C^{H}{}_{j\leftarrow i}$. We can define the total directional contributions from others to variable i (FROM) as $C^{H}{}_{i\leftarrow\bullet} = \sum_{j=1}^{K}\tilde{\theta}_{ij}{}^{H} \quad for \quad j \neq i$ and total directional contribution from i to others in the system (TO) as: $C^{H}{}_{\bullet\leftarrow i} = \sum_{i=1}^{K}\tilde{\theta}_{ij}{}^{H} for \quad i \neq j$. The net directional connectedness (NDC) is therefore $C^{H}{}_{\bullet\leftarrow i} - C^{H}{}_{i\leftarrow\bullet}$.

This method has proved very useful in many areas, such as evaluating systemic risk in financial markets (Bubák et al., 2011; Giglio et al., 2016; Zhou et al., 2012). It has also become popular in discussing energy-related topics (e.g., Antonakakis et al., 2014; Awartani and Maghyereh, 2013; Maghyereh et al., 2016; Zhang, 2017).

4. Data

This paper uses time-series data for Japan, the United States, and Germany. The data are in a monthly frequency, from February 2000 to July 2016. For natural gas prices, the US spot price at the Henry Hub terminal in Louisiana is used, and Japan's data are Indonesian LNG prices in Japan. These two data series are collected from the International Monetary Fund Primary Commodity Prices. We use data from Statistisches Bundesamt to obtain Germany's natural gas import price index.[1] Figure 1, which plots our sample data, shows that, although prices are not always the same, the pricing patterns are generally consistent before the 2008 GFC. However, after the crisis, clear departures from these patterns emerge. Among the early similarities in pricing patterns in Japan and Germany are that natural gas prices are largely indexed to oil prices in these markets. After this indexation is phased out (e.g., Erdős, 2012; Lin and Li, 2015; Ramberg and Parsons, 2012), the price divergence becomes more obvious.

(Insert Figure 1 about here)

Two country-specific demand factors are used in the model: the growth rate of natural gas consumption and the growth rate of the gross domestic product (GDP). Two country- specific supply factors are included: the growth rate of net natural gas imports and of indigenous production of natural gas in each country. The Baltic dry index is also used as a proxy for global economic conditions. Oil prices include three

[1] To be comparable, we adjust the price index series to a real price series in Figure 1.

benchmark prices: WTI prices in the US market, Brent prices in the German market, and Dubai prices for Japanese LNG. The sources of all data are given in detail in Table 2.

(Insert Table 2 about here)

All variables are converted into a growth rate to ensure stationarity conditions for the VAR model.

5. Empirical results

A seven-variable VAR model is estimated for each country. The results are based on a 10-period-ahead (as suggested by Diebold and Yilmaz (2009) and further discussed by Zhang (2017)) forecasting error variance decomposition matrix.[2] The empirical results for the full sample and rolling-windows estimation are reported in sections 5.1 and 5.2. Section 5.3 gives subsample estimations around the 2008 GFC (pre-crisis and post-crisis period). The choice of subsamples is not based on any formal structural break test; rather, it is an ad hoc case study following the recent literature on energy financialization, such as Zhang (2017), who emphasizes the role of the 2008 GFC on the international energy market. The date chosen here is when Lehman Brothers went bankrupt.

5.1 Full sample analysis

[2] The result of variance decomposition is sensitive to the choice of H when it is smaller than the order of the VAR model, but it converges to a constant value when H is higher than the lag orders. For more discussion, see Diebold and Yilmaz (2009).

Table 3 summarizes the connectedness for each market. It shows clear differences across markets and, notably, results for the United States vary from those for the other two markets. First, oil price changes contribute significantly to the system for Japan and Germany, 62.77% and 50.26%, respectively, whereas it only offers 23.13% to the system for the United States. A similar pattern is also seen in the system's contribution to natural gas prices. The system (excluding the variable itself) contributes 48.30% to the variation in natural gas prices in Japan and 55.88% in Germany, but only 26.73% in the United States. Oil is the biggest net directional connectedness (NDC)/contributor and natural gas is the biggest net recipient in Japan and Germany, whereas it does not show such a structure in the United States.

(Insert Table 3 about here)

Looking further into the results on how much natural gas price changes gain from the system reveals more interesting information (see Table 4). These results are also plotted in Figure 2 for comparison.

(Insert Table 4 about here)

The growth rate of gas consumption and production are the top two contributors to gas prices in the US market. They are, however, shown to be at low levels—merely 7.69% and 5.76%, respectively. Oil price changes also have very low share of influence (only 5.18% and ranking number 3 in all five factors) in the US market. The corresponding values for Japan and Germany are 29.38% and 28.07%, respectively, which provides evidence of oil indexation in these two markets. It is noteworthy that the entire system in the United States together contributes only slightly over one-quarter of the variation in the US gas price. The remaining shares are due to the autoregressive part of gas price changes.

(Insert Figure 2 about here)

Market fundamentals in Japan and Germany, including domestic production, imports, and consumption, are the least important (see Panel 2 in Table 4). In contrast to the US case, oil prices are the dominant factor in these two markets. The change in oil prices alone contributes to over 28% in both countries. Because of the anchor effect of oil prices, the system (other than gas) contributes notably more than the United States to gas price changes, with a total of over 50%, which further shows that oil indexation is more obvious in these two countries than in the United States. This finding is consistent with the previous literature (e.g., Ji et al., 2014). In addition, the fundamentals are more important in determining gas prices in Germany than Japan because German gas prices have begun to be linked to European hub prices, and thus they respond to fundamentals more than the Japanese gas prices do.

5.2 Rolling-windows estimation

Over the full sample period, market conditions have continually changed. Consequently, one would expect to see that the structure/mechanism of this system may be time varying. In order to allow for such possibilities, the rolling-window estimation is used for each country to show the relationships in a dynamic manner. Given the constraints of sample size, we chose half the total samples as the window size, which results in a total of 99 observations for each window.

All three countries show clear evidence of time-varying patterns. Given that we are most interested in oil indexation, following the previous section, only the rolling-windows version of oil's contribution to natural gas price changes is reported in Figure 3.[3]

(Insert Figure 3 about here)

Overall, oil's contribution to gas prices in Japan and Germany shows a declining trend in recent years, which is to be expected. In the German market, oil indexation was gradually replaced by hub indexation, which has been more independent from oil prices since 2009. This is because of surplus LNG supply due to diminished demand in the US market after the shale gas revolution and weak demand in European gas markets due to the financial crisis (IEA, 2014). In Japan, after the historically high

[3] The date marked in the graph is the month of the end of each window. Other rolling-window results are available upon request from the corresponding author. Four lags for each rolling window are used to make the results comparable.

prices for LNG due to shocks from the Fukushima nuclear accident, Japan tried harder to decouple LNG and oil prices and procured a significant amount of spot LNG cargo priced lower than oil-indexed LNG prices in the past few years. The declining trend shows a transition away from oil indexation, which is favorable, given that current prices do not reflect local market fundamentals.

Once again, the US case is clearly different from that in the other two countries (oil does not contribute much to the dynamics of gas prices), whereas Japan and Germany share some common features. In the United States, the contribution of oil prices to natural gas prices increases a bit after the 2008 GFC but remains relatively low. After the GFC in 2008, oil price changes increasingly contributed to gas price changes—over 40% in both Japan and Germany (over 45% in Japan)—before falling significantly in both markets in recent years.

5.3 Subsample analysis

Rolling-windows analysis shows that the system may experience structural changes. It is also worth noting again that this section does not aim to detect structural changes in the system but, rather, focuses on the role of the GFC. In fact, some existing studies (e.g., Geng et al., 2016c; Wakamatsu and Aruga, 2013) show that the shale gas revolution beginning in 2006 has changed the relationship in international natural gas markets. However, this is not the focus of our paper. The exact breakpoint of the system has no fundamental impact on our results, though it is worthy of future study.

The degree of contribution by variables in the system to gas price changes is reported in Table 5.

(Insert Table 5 about here)

A few observations can be made. First, the role of oil prices in determining gas prices declines in the two oil-indexed markets: Japan and Germany. However, oil prices remain the leading factor in gas prices in Japan and Germany in both periods. This declining role of oil prices suggests that gas prices are increasingly independent from oil prices. This is consistent with the business practice in both countries, in which more spot indexes were added to the price formula.

Second, market fundamentals play a more important role in the US market. The role of gas production and consumption has become much more important since 2008 than it was beforehand. However, in both Japan and Germany, the role of local market fundamentals has weakened. It is possible that although hub prices are increasingly used in the pricing formula, hub prices are based on TTF (in the case of Germany), Henry Hub, or NBP, which do not reflect German or Japanese market fundamentals.

Third, in Japan and Germany, the systemic impact declines after the GFC. This can be linked to the financialization of energy markets (e.g., Cheng and Xiong, 2013; Creti et al., 2013; Creti and Nguyen, 2015) for several reasons. Other than fundamentals, the financial market (i.e., futures market) has a strong impact on prices—in other words, price dynamics are affected less by macroeconomic factors than by trading behaviors in financial markets.

The empirical results reported above demonstrate that market fundamentals are not the cause of the Asian premium. Gas prices in Japan, however, have clearly been much higher relative to those in the other two markets and the Japanese LNG prices remained high for almost four years, before falling in early 2015. The sharp increase in Japanese gas prices coincides with the Fukushima nuclear accident, which raised demand for natural gas in Japan almost immediately, as well as increasing demand in China. However, no evidence indicates that such sharp changes are possible. In other words, demand factors are relevant but cannot possibly provide a full explanation. Empirically, we find that after the 2008 GFC, although oil's contribution to variations in the Japanese LNG price falls from 38.14% to 17.57%, the total contribution of market fundamentals[4] does not change much: 31.93% before the crisis and 29.20% after the crisis; and oil price remains to be the most significant single determining factor of oil prices.

Given that the total contribution of fundamental factors does not change much in our subsample analysis, we propose here that the price changes may simply be due to unclear fundamental values and subsequent speculative trading in the market. Without a trading hub in the Japanese market, it is harder for the participants in the gas market to find the correct (fundamental) value, which leads to an inefficient market. External shocks, changes in expectations, and even market sentiment can have profound impacts on gas prices. Of course, we have to acknowledge that the evidence here does not enable us to formally test this hypothesis.

6. Conclusions

[4] Calculated using "TOTAL" minus "OIL" in Table 5.

This paper investigates the cause of the Asian premium in natural gas prices through a cross-country study. We use a VAR-based time-series approach to show how much supply and demand market fundamentals, global economic conditions, and oil prices contribute to variations in gas pricing in three countries—Japan, the United States, and Germany, which are the world's three major gas markets. Our empirical results indicate clear cross-country differences and time-varying patterns and enable us to comment on the causes of the Asian premium.

The full sample analysis shows that oil price changes are the most important contributor to the dynamics of natural gas prices in Japan and Germany. The impacts from market fundamentals and global economic conditions differ from country to country. Economic growth, a demand factor, is important in the German price, whereas global economic conditions are more influential on the Japanese price. Consumption of natural gas contributes the most to changes in the US gas price, though only 7.69%. Although both consumption and production are the most important factors in determining natural gas prices in the US market, fundamental factors (at least used in this paper) collectively account for only around 27% of the price.

Through a rolling-windows and subsample analysis, we show that a time-varying pattern exists in all markets, particularly in Japan and Germany. The contribution of oil price changes has declined significantly, which provides supporting evidence of an oil-gas decoupling hypothesis. The declining role of fundamentals in the US market shows that pricing mechanisms in international natural gas markets have changed.

Given the recent trend toward the financialization of energy markets, natural gas prices are expected to respond less to market fundamentals and more to financial markets and trading mechanisms.

This study confirms that the Asian premium is not caused by market fundamentals and is more likely due to oil indexed pricing mechanisms in the gas market than to market fundamentals. These results provide further evidence for ongoing debates on the transition from oil indexation to a hub-pricing mechanism in East Asia.

The results support the argument that a transition from oil indexation to hub pricing is desirable. The United States has already begun to use hub pricing, so the role of its fundamentals is most essential among the three countries. Germany is in the process of shifting from oil indexation to hub pricing. Since Japan is still using oil indexation and exploring a transition, the role of its fundamentals therefore has the smallest impact on the country's gas prices. Because oil indexation fails to reflect market fundamentals in the natural gas markets, it will not be able to lead to efficient allocation (Shi and Variam, 2016). The development of financial markets, such as a futures market, further reinforces the need for local natural gas hubs (Shi et al., 2016).

The results also suggest that the transition in the pricing mechanism should continue especially while oil prices remain low. The previous high oil price benefited the sellers, so they lacked the motivation to coordinate transition. At present, low oil prices make buyers complacent because oil-indexed gas prices are low and converging to spot prices. However, a sluggish transition is not in buyers' long-term interest as oil indexation can cause market failure (Shi and Variam, 2017), and oil prices may go up in the future, thus the Asian premium will return sooner or later. Moreover, such price convergence will make it less painful for both buyers and sellers to switch pricing mechanisms as the difference between the two alternatives is small.

For companies that sign long-term gas and LNG contracts, the findings suggest that oil indexation is still acceptable. However, they should be prepared to change their price benchmark in the future from now on.

References

Antonakakis, N., Chatziantoniou, I., Filis, G., 2014. Dynamic spillovers of oil price shocks and economic policy uncertainty. Energy Economics 44, 433–447.

Asche, F., Misund, B., Sikveland, M., 2013. The relationship between spot and contract gas prices in Europe. Energy Economics 38, 212–217.

Asche, F., Osmundsen, P., Sandsmark, M., 2006. The UK market for natural gas, oil and electricity: are the prices decoupled? The Energy Journal 27, 27–40.

Awartani, B., Maghyereh, A.I., 2013. Dynamic spillovers between oil and stock markets in the Gulf Cooperation Council countries. Energy Economics 36, 28–42.

Bachmeier, L.J., Griffin, J.M., 2006. Testing for market integration crude oil, coal, and natural gas. The Energy Journal 27, 55–71.

Blank, S., 2007. Can East Asia dare to tie its energy security to Russia and Kazakhstan? Journal of East Asian Affairs, 93-137.

Brigida, M., 2014. The switching relationship between natural gas and crude oil prices. Energy Economics 43, 48–55.

Brown, S.P., Yücel, M.K., 2008. What drives natural gas prices? The Energy Journal 29, 45–60.

Bubák, V., Kocenda, E., Zikes, F., 2011. Volatility transmission in emerging European foreign exchange markets. Journal of Banking & Finance 35, 2829–2841.

Caporin, M., Fontini, F., 2017. The long-run oil-natural gas price relationship and the shale gas revolution. Energy Economics 64, 511-519.

Cheng, I.-H., Xiong, W., 2013. The financialization of commodity markets. Review of Financial Economics 6, 419–441.

Creti, A., Joets, M., Mignon, V., 2013. On the links between stock and commodity

markets' volatility. Energy Economics 37, 16–28.
Creti, A., Nguyen, D.K., 2015. Energy markets? Financialization, risk spillovers, and pricing models. Energy Policy 82, 260–263.
Diebold, F.X., Yilmaz, K., 2009. Measuring financial asset return and volatility spillovers, with application to global equity markets. Economic Journal 119, 158–171.
Diebold, F.X., Yilmaz, K., 2012. Better to give than to receive: Predictive directional measurement of volatility spillovers. International Journal of Forecasting 28, 57–66.
Diebold, F.X., Yilmaz, K., 2014. On the network topology of variance decompositions: Measuring the connectedness of financial firms. Journal of Econometrics 182, 119–134.
Erdős, P., 2012. Have oil and gas prices got separated? Energy Policy 49, 707–718.
Geng, J.B., Ji, Q., Fan, Y., 2016a. The behaviour mechanism analysis of regional natural gas prices: A multi-scale perspective. Energy 101, 266-277.
Geng, J.B., Ji, Q., Fan, Y., 2016b. The impact of the North American shale gas revolution on regional natural gas markets: Evidence from the regime-switching model. Energy Policy 96, 167-178.
Geng, J.B., Ji, Q., Fan, Y., 2016c. How regional natural gas markets have reacted to oil price shocks before and since the shale gas revolution: A multi-scale perspective. Journal of Natural Gas Science and Engineering 36, 734-746.
Giglio, S., Kelly, B., Pruitt, S., 2016. Systemic risk and the macroeconomy: An empirical evaluation. Journal of Financial Economics 119, 457–471.
Giziene, V., Zalgiryte, L., 2015. The assessment of natural gas pricing. Procedia-Social and Behavioral Sciences 213, 111–116.
Hamilton, J.D., 1994. Time Series Analysis. Princeton University Press, Princeton.
Hartley, P.R., Medlock, K.B., III, Rosthal, J.E., 2008. The relationship of natural gas to oil prices. The Energy Journal 29, 47–65.
Hayashi, M., Hughes, L., 2013a. The Fukushima nuclear accident and its effect on global energy security. Energy Policy 59, 102–111.
Hayashi, M., Hughes, L., 2013b. The policy responses to the Fukushima nuclear accident and their effect on Japanese energy security. Energy Policy 59, 86–101.
Hulshof, D., van der Maat, J.-P., Mulder, M., 2016. Market fundamentals, competition and natural-gas prices. Energy Policy 94, 480–491.
IEA, 2013. Developing a natural gas trading hub in Asia: Obstacles and opportunities. International Energy Agency, Paris.
IEA, 2014. The Asian quest for LNG in a globalizing market. International Energy Agency, Paris.
Ji, Q., Geng, J.B., Fan, Y., 2014. Separated influence of crude oil prices on regional natural gas import prices. Energy Policy 70, 96–105.
Koop, G., Pesaran, M.H., Potter, S.M., 1996. Impulse response analysis in nonlinear multivariate models. Journal of Econometrics 74, 119–147.
Li, R., Joyeus, R., Ripple, R.D., 2014. International natural gas market integration.

The Energy Journal 35, 159–179.
Lin, B., Li, J., 2015. The spillover effects across natural gas and oil markets: Based on the VEC-MGARCH framework. Applied Energy 155, 229–241.
Maghyereh, A.I., Awartani, B., Bouri, E., 2016. The directional volatility connectedness between crude oil and equity markets: New evidence from implied volatility indexes. Energy Economics 57, 78–93.
Mu, X., 2007. Weather, storage, and natural gas price dynamics: Fundamentals and volatility. Energy Economics 29, 46–63.
Neumann, A., 2009. Linking natural gas markets. Is LNG doing its job? The Energy Journal 30, 187–199.
Neumann, A., Von Hirschhausen, C., 2015. Natural gas: An overview of a lower-carbon transformation fuel. Review of Environmental Economics and Policy 9, 64-84.
Nick, S., Thoenes, S., 2014. What drives natural gas prices? A structural VAR approach. Energy Economics 45, 517–527.
Panagiotidis, T., Rutledge, E., 2007. Oil and gas markets in the UK: Evidence from a cointegrating approach. Energy Economics 29, 329–347.
Pesaran, H.H., Shin, Y., 1998. Generalized impulse response analysis in linear multivariate models. Economics Letters 58, 17–29.
Ramberg, D.J., Parsons, J.E., 2012. The weak tie between natural gas and oil prices. The Energy Journal 33, 13–35.
Serletis, A., Shahmoradi, A., 2005. Business cycles and natural gas prices. OPEC Review 29, 75–84.
Shi, X., Li, Y., and Reshetova E., 2016. Bottom-up design of a gas futures market in East Asia: Lessons from the Dojima Rice Exchange. Natural Gas Industry B, 3 (4), 377-386.
Shi, X., Variam, H.M.P., 2016. Gas and LNG trading hubs, hub indexation and destination flexibility in East Asia. Energy Policy 96, 587-596.
Shi, X., Variam, H.M.P., 2017. East Asia's gas-market failure and distinctive economics: A case study of low oil prices. Applied Energy (forthcoming)
Siliverstovs, B., L'Hegaret, G., Neumann, A., Von Hirschhausen, C., 2005. International market integration for natural gas? A cointegration analysis of prices in Europe, North America and Japan. Energy Economics 27, 603–615.
Sims, C.A., 1980. Macroeconomics and reality. Econometrica 48, 1–48.
Stern, J., 2014. International gas pricing in Europe and Asia: A crisis of fundamentals. Energy Policy 64, 43–48.
Stern, J., 2016. The new Japanese LNG strategy: A major step towards hub-based gas pricing in Asia. Oxford: Oxford Institute for Energy Studies.
Tong, X., Zheng, J., Fang, B., 2014. Strategic analysis on establishing a natural gas trading hub in China. Natural Gas Industry B 1, 210-220.
Villar, J.A., Joutz, F.L., 2006. The relationship between crude oil and natural gas prices. Energy Information Administration, Office of Oil and Gas.
Vivoda, V., 2014. Natural gas in Asia: Trade, markets and regional institutions. Energy Policy 74, 80–90.

Wakamatsu, H., Aruga, K., 2013. The impact of the shale gas revolution on the US and Japanese natural gas markets. Energy Policy 62, 1002–1009.
Zhang, D., 2017. Oil shocks and stock markets revisited: Measuring connectedness from a global perspective. Energy Economics 62, 323-333.
Zhou, X., Zhang, W., Zhang, J., 2012. Volatility spillovers between the Chinese and world equity markets. Pacific-Basin Finance Journal 20, 247–270.

Tables and Figures

Table 1: H-period-ahead forecasting error variance decomposition results

	y_1	y_2	$\cdots$	y_K	From
y_1	$\tilde{\theta}_{11}^H$	$\tilde{\theta}_{12}^H$	$\cdots$	$\tilde{\theta}_{1K}^H$	$\sum^K \tilde{\theta}_{1j,j\neq 1}^H$
y_2	$\tilde{\theta}_{21}^H$	$\tilde{\theta}_{22}^H$	$\cdots$	$\tilde{\theta}_{2K}^H$	$\sum^K \tilde{\theta}_{2j,j\neq 2}^H$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$
y_K	$\tilde{\theta}_{K1}^H$	$\tilde{\theta}_{K2}^H$	$\cdots$	$\tilde{\theta}_{KK}^H$	$\sum^K \tilde{\theta}_{Kj,j\neq K}^H$
To	$\sum^K \tilde{\theta}_{i1,i\neq 1}^H$	$\sum^K \tilde{\theta}_{i1,i\neq 2}^H$	$\cdots$	$\sum^K \tilde{\theta}_{i1,i\neq K}^H$	$\frac{1}{K}\sum^K \tilde{\theta}_{i1,i\neq j}^H$

Table 2: Variables of interest and sources

Notations	Details	Data resource	Factor categories
GAS	Growth rate of gas prices	IMF Primary Commodity Prices& *Statistisches Bundesamt*	N/A
OIL	Growth rate of oil prices	IMF Primary Commodity Prices	Market factor
CON	Growth rate of gas consumption	IEA monthly statistics	Demand factor
GRO	GDP growth	OECD Data: Industrial Production	Demand factor
PRO	Growth rate of Indigenous Production of natural gas	IEA monthly statistics	Supply factor
IMP	Growth rate of net import of natural gas	IEA monthly statistics	Supply factor
BAL	Baltic dry index (growth rate)	Bloomberg	General economic condition

Notes: Consumption, production and supply are all seasonally adjusted before calculating their growth rates. All variables are monthly frequency from February/2000 to July/2016, which yields a totally of 198 observations.

Table 3: Summary of the connectedness table

		Gas	OIL	CON	GRO	IMP	PRO	BAL
USA	FROM	26.73%	22.08%	22.46%	28.35%	15.95%	23.64%	23.94%
	TO	29.21%	23.13%	17.62%	18.28%	24.21%	22.61%	28.07%
	NDC	2.48%	1.06%	-4.84%	-10.07%	8.26%	-1.03%	4.14%
JPN	FROM	48.30%	21.19%	21.48%	33.32%	32.88%	30.19%	23.04%
	TO	13.34%	62.77%	22.57%	13.15%	35.24%	15.37%	47.97%
	NDC	-34.95%	41.58%	1.09%	-20.18%	2.36%	-14.82%	24.93%
GER	FROM	55.88%	23.17%	34.07%	29.60%	43.31%	27.95%	23.29%
	TO	19.60%	50.26%	38.99%	16.92%	51.01%	33.01%	27.50%
	NDC	-36.28%	27.08%	4.92%	-12.68%	7.69%	5.06%	4.21%

Table 4: Contributions/rankings to the variation of natural gas price changes

Panel I. Contributions

Countries	OIL	CON	GRO	IMP	PRO	BAL	TOTAL
USA	5.18%	7.69%	2.63%	2.27%	5.76%	3.21%	26.73%
JPN	29.38%	2.77%	3.08%	2.82%	1.38%	11.32%	50.76%
GER	28.07%	4.28%	10.54%	4.34%	3.23%	5.43%	55.83%

Panel II. Rankins

Ranks	USA	Japan	Germany
1	Consumption	Oil price	Oil price
2	Production	Baltic	Growth
3	Oil price	Growth	Baltic
4	Baltic	Net Import	Net Import
5	Growth	Consumption	Consumption
6	Net Import	Production	Production

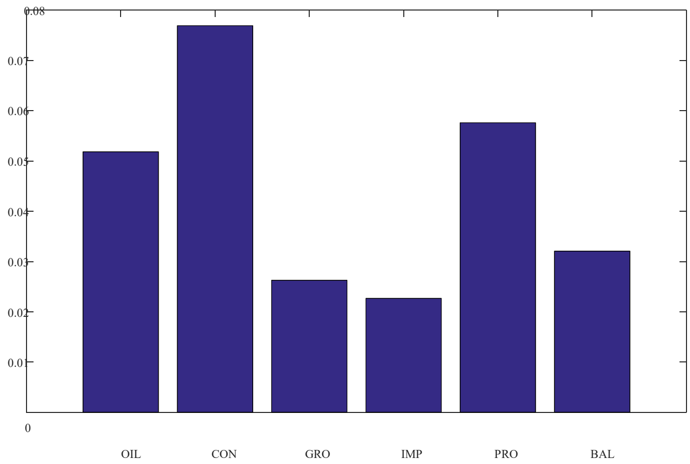
Notes: One minus total gives the contribution due to natural gas price change itself. Lags are chosen by minimizing Akaike information criteria (AIC). ‘JPN=Japan’, ‘USA=United States’, and ‘GER=Germany’.

Table 5: Contributions to the variation of natural gas price changes: sub-samples

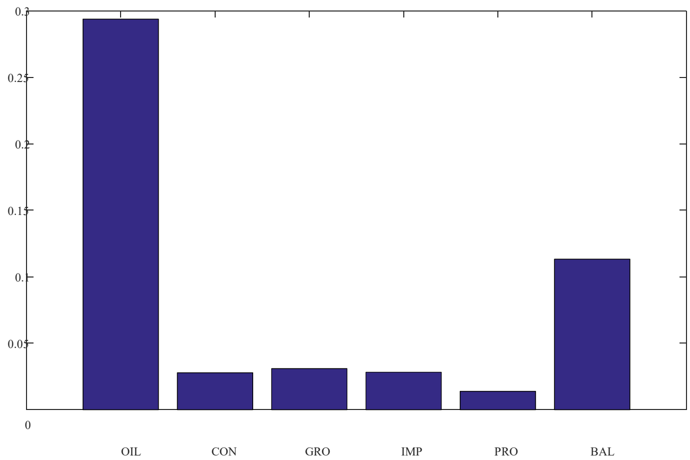
		OIL	CON	GRO	IMP	PRO	BAL	Total
USA	PRE08	4.58%	6.27%	4.73%	4.80%	5.48%	5.70%	31.56%
	POS08	7.22%	10.31%	4.02%	4.09%	14.30%	5.37%	45.31%
JPN	PRE08	38.14%	8.47%	13.07%	4.75%	4.15%	1.49%	70.07%
	POS08	17.57%	5.79%	9.92%	4.51%	5.89%	3.09%	46.77%
GER	PRE08	26.66%	6.09%	6.66%	9.29%	4.60%	2.79%	56.08%
	POS08	14.60%	5.66%	7.34%	8.76%	7.54%	4.85%	48.76%

Notes: One minus total gives the contribution due to natural gas price change itself. Lags are chosen by minimizing Akaike information criteria (AIC). 'JPN=Japan', 'USA=United States', and 'GER=Germany'.

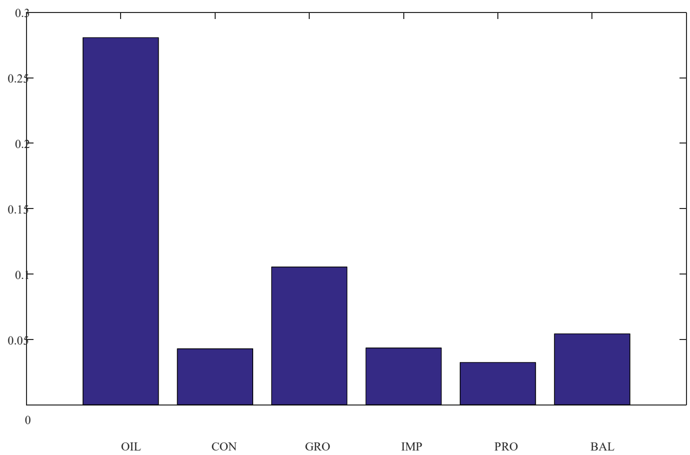
Figure 1: Monthly natural gas prices for three countries



(a) the US

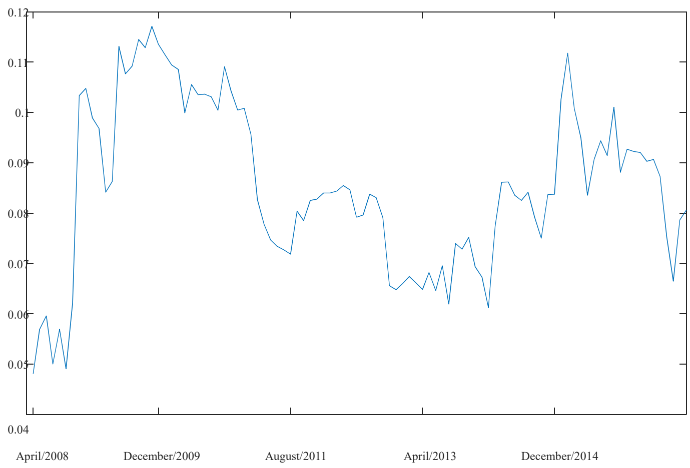


(b) Japan

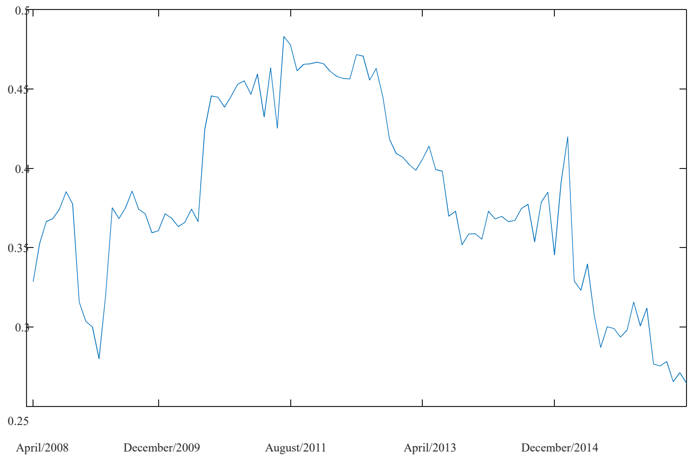


(c) Germany

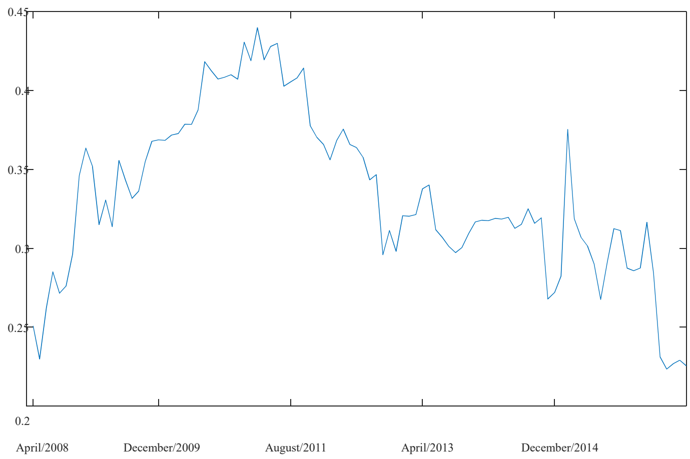
Figure 2: Contributions to natural gas price changes of three countries



(a) the US



(b) Japan



(c) Germany

Figure 3: Rolling-windows estimation of oil's contribution