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Investigation of the price linkage between Asian LNG spot and Far East Asian LNG prices and its implications

Muhammad Anas Pradipta[1,*]

SKK Migas, Wisma Mulia Building 31st Floor,
Jl. Jend. Gatot Subroto No. 42, Jakarta, 12710.

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Abstract. For so many times, Far East Asian liquid natural gas (LNG) buyers have been using price linked to crude oil-indexed, now they need to find another alternative pricing formula for their crucial energy supply as a better price structure that could reflect the market is needed. LNG spot price is expected to be the pillar for the future LNG trading, especially for Far East Asia Market. As less and less long-term contracts are signed in the Far East Asia Market, this creates an additional demand for the LNG in the spot market, while it raises some issues about the presence of different LNG pricing mechanisms. Most of the LNG spot prices in Asia are indexed to the relatively low natural gas prices in Atlantic Basin. Furthermore, the advancement of drilling technology in the US drives down its natural gas prices, resulting in price discrepancies between Asian LNG spot and East Asian LNG prices. This study investigates whether there is a price linkage between Asian LNG spot and East Asian LNG prices. This study comprehends 91 observations collected from January 2010 to July 2017. Johansen co-integration tests were carried out to examine the existence of long-run relationship on the spot, Japanese and South Korean LNG prices. The Augmented Dickey-Fuller (ADF), Phillip-Perron (PP), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests were conducted first before proceeding to the co-integration tests. The results showed that Asian LNG spot prices did not have price linkage for monthly averages of Japanese and South Korean LNG prices. The analyses also indicated that Taiwan LNG markets move together with Asian LNG spot markets. As a conclusion, the results inferred that supply dependency on LNG spot cargoes governed the price linkage among these Asian LNG markets. The use of gas indexed LNG price mechanism did not reflect the economic fundamentals in Asia-Pacific Basin.

JEL Classification: Q41
Keywords: Price linkage, Johansen co-integration, augmented Dickey-Fuller, Phillip-Perron, and Kwiatkowski-Phillips-Schmidt-Shin, unit root tests, Far East Asian LNG spot prices, LNG spot and short-term cargoes, long-term contracts, spot prices, energy: demand and supply, prices

1. Introduction

1.1 Background

For many decades, energy is one of the main issues for almost all of the countries in the world. For a country that has an abundant supply, the concern is how to sell it at the appropriate price, while for the buyer country is how to buy energy supply at the lowest price. International Gas Union (IGU) in their 2010 report state the imbalance between energy supply and demand situations made energy projection and policy crucial to be a significant factor for a country's long-run strategy. According to International Energy Agency (IEA) projection in World Energy Outlook 2014, there will be a strong increase in energy demand over the coming decades. As a result of increasing energy demand, the world nowadays is trying to diversify their energy need from fossil fuel based to a more environmental friendly coming from renewable energy such as solar, hydro or wind power.

* Corresponding author
E-mail address: mapradipta@skkmigas.go.id

About the energy diversification, many of the experts believe gas plays important roles as the transition energy from fossil fuel to renewable energy. According to BP's energy outlook (2013), natural gas is the fastest growing fossil fuel and its global consumption increases at an average annual rate of 2 percent. The Far East Asian region (Japan, Korea, and Taiwan) is the largest gas importer in the world. As a result, it is likely to say that most of the LNG producer nowadays is trying to sell their production to country within Far East Asia Region. As in 2012, United States' role in the gas market has changed from consumer to producer country, that means Far East Asia Region will play more important roles as the consumer in the future. Certainly, the key concern for this region is how to buy an optimize LNG price from the producers.

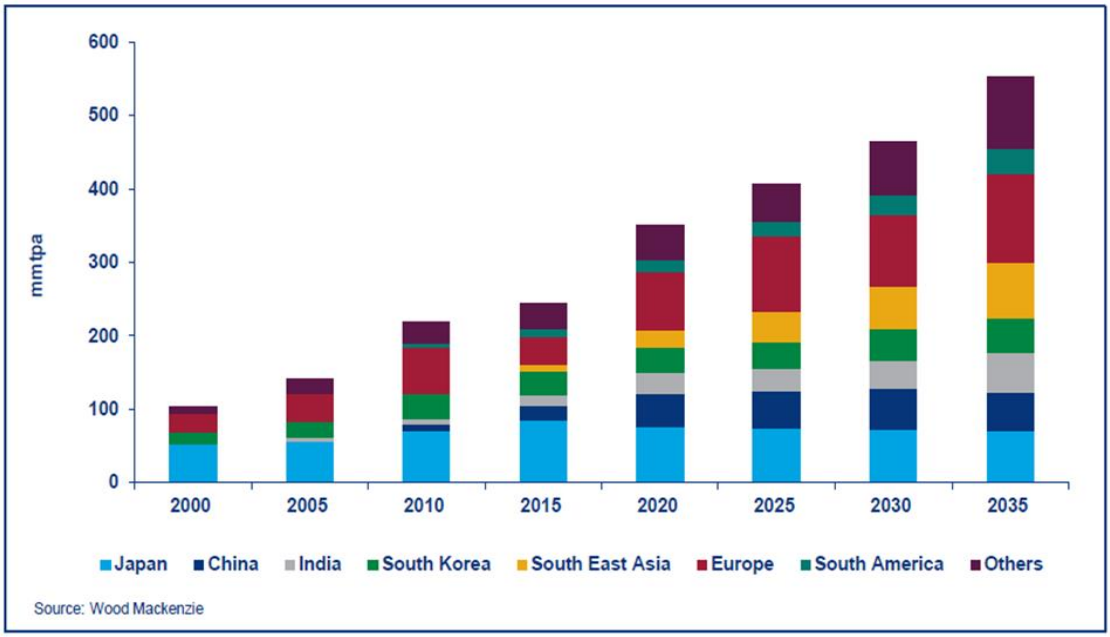

Figure 1: Global LNG Demand Overview

In the Asia-Pacific markets, two pricing mechanism exist: the long-term LNG contract and the spot LNG pricing. The long-term contract mechanism uses the crude oil indexation in its pricing formula, whereas, spot LNG pricing mirroring the gas hub price indexation. LNG long-term contact has been the backbone of LNG trade in Asia for years. It gives a certain degree of securities to both buyers and sellers. Conversely, spot LNG pricing is still at a nascent stage in this region. There is not a fixed structure how to establish these spot prices.

In complement to LNG long-term contract purchases in Asia, over the past decade, the demand for spot LNG trades have grown significantly. This case, of course, raises some concerns for the LNG players in the region, because there is no gas trading hub in Asia. Hence, the fairness and transparency of LNG spot prices are difficult to be justified. When the LNG buyers in Asia procure the spot cargoes from Atlantic Basin, they often use National Balancing Point (NBP - a gas hub in the UK), or Henry Hub (HH - a gas hub in the US) gas prices as their price references plus additional costs, such as transportation costs.

Over the past years, there were a number of significant events which have profound effects on the evolution of Asian LNG spot prices. Globally, there is an increase in crude oil prices due to a strong and sustained demand from developing countries in the mid of depletion of this non-renewable resources in a reachable area. Exploration companies need to go to offshore deepwater, for example, to meet the intense fossil fuel demands. Therefore, the Asian LNG spot prices increase to the level of mature Far East Asian LNG prices, governed by the majority of long-term contracts. Furthermore, the breakthrough shale gas revolution in the US changes the global scene by creating a massive

downward pressure to HH gas prices. The US succeeds to increase its hydrocarbon productions by exploiting the shale formations. This situation encourages many LNG industry players to thinking of an alternative LNG pricing Mechanism.

Meanwhile, the global LNG outlook was exacerbated by demand shock in Asia. Japan needs to secure additional LNG shipments in the wake of Fukushima earthquake in 2011, whereas, its neighboring countries keep searching for extra supplies to meet their domestic natural gas demands. Since most of the LNG producing countries were already bound to long-term contracts with several LNG buyers in Asia, there was not enough capacity for the suppliers in the area to meet the surging demands. As Japan and the rest of LNG buyers in Asia wanted to have additional purchases on top of their existing supplies, they began to find the LNG cargoes from other countries outside Asia-Pacific Basin. As seen in figure 2, the percentage of Spot or Short Term transaction has been gradually increasing since 2008. Because the nature of the LNG purchase is to complement the current supplies, some of these Asian countries engaged in spot or short-term LNG contract prices. In most cases, they need to pay premium prices to buy these LNG shipments. This situation leads to a significant spot price discrepancy between Asia-Pacific and Atlantic Basins. Thus, created an arbitrage opportunity to sell the spot cargoes from other LNG markets.

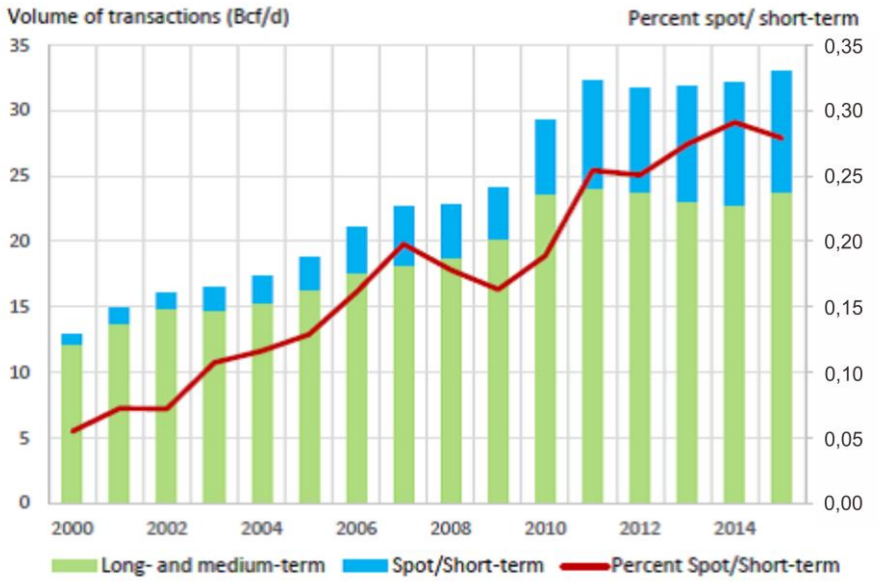

Figure 2: World LNG Trade by Contract Duration 2000 – 2015
Sources: GIIGNL and EIA - Perspectives on the Development of LNG Market Hubs in the Asia Pacific Region

Discussions about creating a natural gas trading hub in Asia have been touted by many LNG players because there is an urgent need to reformulate the long-standing crude oil indexation in the long-term LNG contract pricing mechanisms. Furthermore, spot trading methodology is preferred because it reflects the supply and demand fundamentals in the region. Nevertheless, it is important to record that spot gas or hub prices will not guarantee a lower price to procure LNG cargoes.

In the current issue, the premium of Asian LNG spot prices can also be viewed as a response to the high prices resulting from the existence of long-term contracts and somewhat region's supply and demand fundamentals for the additional supplies. The construction of Asian LNG spot prices is to some extent derived from the prevailing Asian LNG prices, which are governed mostly by crude oil price indexation in the long-term contracts. Theoretically, rational sellers will not give lower prices than the prevailing market prices in the region when the demands are tight. Moreover, a price discount appears when the demand has receded, which can usually be observed during summer.

It is, therefore, interesting to investigate the presence of price linkages between Asian LNG spot and Far East Asian LNG prices. If a price linkage exists for particular countries, it could imply that those countries can use the LNG spot price as reference price during their price discovery process when purchasing the LNG. Furthermore, it could mean that there is LNG market integration to some extent between Asia-Pacific and Atlantic Basins as well because most Asian LNG spot prices are derived from gas hubs in the Atlantic Basin. On the other hand, if these Asian LNG prices move independently, their prices discovery process is not influenced by the LNG spot price. Nevertheless, the fact that Asian LNG spot prices are high could be due to the lack of liquidity and transparency in Asian LNG markets.

1.2 Purpose of The Study

With a growing number of LNG spot or short-term cargo activities, the consumers in the region would have two kinds of LNG pricing mechanisms, i.e., spot vs long-term contract, which would affect their overall portfolios. Therefore, the purpose of this study is to examine the behaviour of Asian LNG spot prices towards Japanese, Korean, and Taiwanese (JKT) LNG prices, because these long-term contract prices are well established and mostly adopted in the Asia-Pacific Basin, and many export scale LNG projects are relying their investment based on this price mechanism.

Because it is known that Asian LNG spot cargoes usually use gas hub prices in Atlantic Basin, having no long-run relationships among the Asian LNG spot and Far East Asian LNG prices would imply that there is a gap between the Asia-Pacific and Atlantic Basin markets. A number of domestic events in the Atlantic Basin are not strong enough to influence the dynamics of LNG market in Asia-Pacific Basin. Conversely, if price linkage is found among these Asian LNG prices, the tests could imply that the market fundamentals in Atlantic Basin have to some extent more influence on those particular countries. The price linkage is expected to exist for countries that are actively purchasing spot LNG cargoes that use gas hub prices in the Atlantic Basin. In the end, this study could contribute to the justification of future Asian LNG pricing mechanism

2. Literature Review

There have been many research papers about the investigation of co-movement of economic variables by applying time series analysis techniques. Aruga (2013) investigated the price linkage between Japanese natural gas prices and other international natural gas prices, i.e., the US and European. Furthermore, Maggiora and Skerman (2009) examined the co-integration relationships between 4 specified European stock markets and the American stock markets. Lastly, Argenton (2012) examined the statistical relationship between prices of imported LNG in Japan and crude oil prices. In those previous studies, the authors used a common methodology which is called co-integration analysis to understand the behavior of the economic variables in the long-term.
Furthermore, many papers have dedicated to this price long-run relationship topic, particularly in the energy industry. Asche, Gjolberg, & Volker (2003) discovered the long-run relationship between crude oil and refined oil products in the UK market, from their monthly price data between 1995 and 1998. Bachmeier, & Griffin (2006) found a weak price linkage prevailed among the crude oil, coal, and natural gas markets, as these type of energy sources were not categorized as one economic market. Finally, Hartley, Medlock, & Rosthal (2008) found the presence of co-movement between natural gas and petroleum markets in the long-run in the US and identified that this relationship could be affected by weather, inventories, and hurricanes in the short-run.

Spot LNG trading in the Asian region is growing at a significant rate, and it is becoming more and more important to find out how the Asian LNG spot price is linking with the Far East Asian LNG prices. However, at the moment, there are no studies that examine the price linkages for the Far Asian LNG markets. This paper will fill this gap and investigate the price linkages among the Asian LNG spot and Far East Asian LNG markets. I believe this study will give a better understanding of the dynamics of Asian LNG spot prices towards largest LNG consuming countries in the Far East Asian region.

3. Data and Methodology

3.1 Data Collection

To proceed with this study, the monthly average Asian LNG prices, which includes Japanese, South Korean and Taiwanese LNG process, and Asian LNG spot prices, were used. The average was calculated using IHS Markit Publication on Gas and LNG prices from January 2010 to July 2017.

Table 1: Data Collection Method

Variables	Description	Source	Periodicity	Unit of Measurement
AsianSpot	Asian LNG Spot Price	IHS Markit	Monthly	US$/MMBTU
JapanLNG	Japan LNG Price	IHS Markit	Monthly	US$/MMBTU
SouthKoreaLNG	South Korea LNG Price	IHS Markit	Monthly	US$/MMBTU
TaiwanLNG	Taiwan LNG Price	IHS Markit	Monthly	US$/MMBTU

In most time series analysis, the data are usually converted to the logs of the data to analyze the relationships between macroeconomic or price variables. Utilizing logged variables would help the residuals to have a more normal distribution. However, the objective of this study is to empirically investigate the underlying parameters of contracts that are specified in levels, not an economic relationship. Having logged variables in the analysis would eliminate some long-run information present, (Argenton, 2012).

3.2 Methodology

Co-integration test is a statistical technique which is able to determine the existence of co-movement among historical economic variables. There are many co-integration techniques have been proposed in the past. Ssekuma (2011) made a comparison study of co-integration methods, i.e., the Engle-Granger method (Engle & Granger, 1987); the Phillips-Ouliaris residual-based tests, for the variance ratio and multivariate trace statistic (Phillips-Ouliaris, 1988); and lastly, the Johansen's procedure in which, rather than utilizing the Ordinary Least Squares (OLS) procedures, establishes cointegrated variables directly on maximum likelihood estimation (Johansen and Juselius, 1990).

Although many research papers have used the Engle and Granger test to investigate the price linkage (Goodwin & Schroeder, 1991), however, Johansen co-integration test is used in this study. It is due to the Johansen co-integration test has more advantageous, such as, more efficient in investigating the economic variables as endogenous in the model, and thus, more handy in a multivariate framework, (Aruga & Managi, 2011). Furthermore, Johansen test is superior over the Engle and Granger test in a bivariate co-integration framework, because Gaussian errors are not required in the Johansen co-integration test, (Darrat, 1998).

A brief theoretical explanation of Johansen co-integration test, (Aruga & Managi, 2011), will be presented here.

Let Yt be the n ×1 vector of the non-stationary variables and k be the order of the vector autoregressive process. Then, the vector auto-regressive model used for the Johansen co-integration test as follows:

$$Y_t = \sum_{i=1}^{k} \prod_i Y_{t-i} + \Phi D_t + \varepsilon_t$$

Where Yt are the endogenous variables of interest (prices of the energy sources), Πi is a $n \times n$ matrix of parameters, Φ is a coefficient parameter, Dt is a deterministic term that includes a constant and a linear time trend, and εt denotes a normally distributed n-dimensional white noise process. Converting this model into the error correction model leads to:

$$\Delta Y_t = \prod Y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \, \Delta Y_{t-1} + \Phi D_t + \varepsilon_t$$

Positive characteristic roots, which is called the eigenvalue. Using this eigenvalue, the trace and maximum eigenvalue tests are performed among the price series.

3.3 Unit Root Testing

But before conducting the Co-integration test, the determinant factors have to be verified for their stationaries. A stationary time series is a situation when the mean of a particular series of data does not vary significantly over a period. In this case, the series fluctuates around the mean value. And it can explain that the data is in the end stationary and lead to meaningful interpretation results. In contrary Kilian and Murphy (2014) incorrectly differencing a variable would cause the impulse response estimates to be inconsistent. For this study, the model is in levels although not all variables are stationary.

The unit root testing should be showed to make sure the variables integrated in the same order. As there are several unit root techniques, for this study researcher will use three common unit root testing (URT) which is the Augmented Dickey-Fuller (ADF), the Philipps-Perron (PP) and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test.

4. Results

The results will be in two parts: quantitative discussion and qualitative discussion. The former explains the results of the econometric tests, and the latter provides some factual arguments to corroborate the conclusion.

4.1 Quantitative Discussion
4.1.1 Unit Root Tests

To decide whether the price variables have a unit root or not, the t-statistic figures of each test will be compared to its corresponding 5 percent t-critical value. If t-statistic is more than t-critical, then the Null Hypothesis can be rejected. The results of both t-statistic and 5 percent t-critical values for Level series are provided in table 2. Furthermore, both t-statistic and 5 percent t-critical values for First Difference series are displayed in table 3.

Table 2: t-statistic values for Level series

t-statistic	Level			5% t-statistic	Level		
	ADF	PP	KPSS		ADF	PP	KPSS
Japan	-1,91168	-0,914321	0,548401	Japan	-2,898623	-2,893956	0,463
South Korea	-0,903014	-1,045777	0,430447	South Korea	-2,895924	-2,893956	0,463
Taiwan	-0,73172	-0,863706	0,576861	Taiwan	-2,894332	-2,893956	0,463
Asian Spot	-1,720185	-1,009742	0,415372	Asian Spot	-2,894332	-2,893956	0,463

Table 3: t-statistic values for First Difference series

t-statistic	Level			5% t-statistic	Level		
	ADF	PP	KPSS		ADF	PP	KPSS
Japan	-5,586913	-5,607436	0,359232	Japan	-2,8994332	-2,894332	0,463
South Korea	-4,278083	-8,091574	0,330282	South Korea	-2,895924	-2,894332	0,463
Taiwan	-6,780116	-12,144468	0,305984	Taiwan	-2,899115	-2,894332	0,463
Asian Spot	-6,183992	-5,786377	0,241835	Asian Spot	-2,894332	-2,894332	0,463

To analyze the figures, the absolute values were compared and the conclusion was constructed accordingly. On the level series, the t-statistic values for both ADF and PP tests are all smaller than 5 percent t-critical values for the same tests. It means that the Null Hypothesis, which is having a unit root, cannot be rejected. All of the price variables are not stationary on the Level series according to ADF and PP tests.

As oppose to the figures in ADF and PP tests, the t-statistic value for KPSS is greater than those of 5 percent t-critical value. Therefore, it means that the Null Hypothesis can be rejected. All of the price variables are stationary on the Level series according to KPSS test.

Now, the First Difference series would be analyzed in the same way to analyze the Level series. The figures of t-statistic value for ADF and PP tests are bigger than those of 5 percent t-critical value for the same tests. It means that the Null Hypothesis can be rejected. All of the price variables are stationary according to ADF and PP tests. In contrast, the figures of t-statistic value for KPSS test are smaller than the corresponding figures of 5 percent t-critical value. It means that the Null Hypothesis cannot be rejected. All of the price variables are stationary on the First Difference series according to KPSS test.

The general conclusion from these unit root test analyses is that the price variables are integrated on the same order on their First Difference series, or I(1). This situation fulfills the prerequisite before proceeding to Johansen co-integration test.

4.1.2 Multivariate Johansen Co-integration Test

In this multivariate Johansen co-integration test, all the economic variables were tested at the same time. The conclusion will be drawn based on each Trace and Max-Eigenvalue analysis. Table 4 and table 5 shows the Trace and Max-Eigenvalue results, respectively. Both t-statistic and 5 percent t-critical will be compared to deduce whether or not the Null Hypothesis can be rejected.

Johansen co-integration test examined whether the rank of the VAR is 1, 2, 3, and so on. The null does not examine whether the variables are co-integrated or not. On the other hand, it tests the VAR model rank. For the conclusion to be valid, the number of rank at maximum should be r = N - 1, where r represents rank and N represents how many variables. If the value of t-statistic is greater than that of 5 percent t-critical, then Null Hypothesis can be rejected. The rank is significant, and it will signify the co-integrating equation. Furthermore, the statement that E-views provide at right after the table should lead to the same quantity of rank usually. If those statements mention the different number of rank, the conclusion based on Trace statistical analysis will be preferred.

Table 4: Trace statistic values of Multivariate co-integration test

Hypothesized No. of CE (s)	Trace Statistic	0,05 Critical Value
None*	65,0335	47,85613
At most 1	27,94301	29,79707
At most 2	14,05878	15,49471
At most 3	2,415734	3,841466

From table 4, the values of Trace Statistic for None are bigger than that of 5 percent t-critical values. Hence, the Null Hypothesis can be rejected, and the results mean that the figures of None are significant. These results lead to a conclusion that there are one cointegrating equation in the multivariate Johansen test based on Trace Statistic.

Table 5: Max-Eigen statistic values of Multivariate co-integration test

Hypothesized No. of CE (s)	Max-Eigen Statistic	0,05 Critical Value
None*	37,09049	27,58434
At most 1	13,88423	21,13162
At most 2	11,64305	14,2646
At most 3	2,415734	3,841466

From table 5, the values of Max-Eigen Statistic for None are greater than that of 5 percent t-critical values. Hence, the Null Hypothesis can be rejected, and the results mean that the figures of None, are significant. These results lead to a conclusion of there are one co-integrating equation in the multivariate Johansen test based on Max-Eigen Statistic.

The general conclusion from Johansen multivariate co-integration tests indicates that there is a weak long-run relationship those five selected Asian LNG prices.

4.1.3 Bivariate Co-integration Test

There would be three bivariate Johansen co-integration tests which examine the price linkage between Asian LNG spot prices against Japanese, Korean, and Taiwanese LNG prices. These tests would give a better understanding of the long-run relationship of Asian LNG spot prices to each East Asian LNG markets.

4.1.3.1 Asian Spot vs. Japan LNG Price

The results of Trace and Max-Eigen statistic values for Asian spot and Japanese LNG prices are displayed in table 6 and 7, respectively.

Table 6: Trace statistic values of Asian spot vs Japan co-integration test

Hypothesized No. of CE (s)	Trace Statistic	0,05 Critical Value
None*	13,0653	15,49471
At most 1	1,196566	3,841466

Table 7: Max-Eigen statistic values of Asian spot vs Japan co-integration test

Hypothesized No. of CE (s)	Max-Eigen Statistic	0,05 Critical Value
None*	11,86874	14,2646
At most 1	1,196566	3,841466

The value of Trace and Max-Eigen statistic for None and At most 1 is smaller than that of 5 percent critical value. Hence the Null Hypothesis cannot be rejected. Furthermore, E-views indicates that there is no co-integrating equation at the 5 percent level.

Thus, we can conclude that there is no long-term relationship between Asian spot and Japanese LNG prices.

4.1.3.2 Asian Spot vs. South Korea LNG Price

The results of Trace and Max-Eigen statistic values for Asian spot and South Korea LNG prices are displayed in table 8 and 9, respectively. Both Trace and Max-Eigen statistic values indicate that there are no cointegrating equations between Asian spot and South Korean LNG Price.

Table 8: Trace statistic values of Asian spot vs. South Korean co-integration test

Hypothesized No. of CE (s)	Trace Statistic	0,05 Critical Value
None*	15,21349	15,49471
At most 1	1,631805	3,841466

Table 9: Max-Eigen statistic values of Asian spot vs. South Korean co-integration test

Hypothesized No. of CE (s)	Max-Eigen Statistic	0,05 Critical Value
None*	13,58619	14,2646
At most 1	1,631805	3,841466

As it was explained in Asian Spot vs. Japan LNG Price part, these results indicate that there is no co-integration between Asian spot and Taiwanese LNG prices.

4.1.3.3 Asian Spot vs. Taiwan LNG Price

The results of Trace and Max-Eigen statistic values for Asian spot and Taiwan LNG prices are displayed in table 10 and 11, respectively. Both Trace and Max-Eigen statistic values indicate that there is one cointegrating equation between Asian spot and Taiwan LNG prices.

Table 10: Trace statistic values of Asian spot vs. Taiwan co-integration test

Hypothesized No. of CE (s)	Trace Statistic	0,05 Critical Value
None*	19,68082	15,49471
At most 1	1,078701	3,841466

Table 11: Max-Eigen statistic values of Asian spot vs. Taiwan co-integration test

Hypothesized No. of CE (s)	Max-Eigen Statistic	0,05 Critical Value
None*	18,60212	14,2646
At most 1	1,078701	3,841466

4.2 Qualitative Discussion

4.2.1 Japan and South Korea LNG Market

Japan and South Korea, the biggest LNG buyer in the world, has traditionally engaged in long-term LNG trades to ensure uninterrupted supplies. It coined the JCC formula which gives stable and affordable LNG prices before the 2000s. The long-term contracts made up a huge portion of its LNG imports. Over the past decade, Japanese companies have signed 56 long-term contracts in 6 countries, (GIIGNL, 2013).

The spot LNG cargoes grew its share starting 2010 to complement the long-term contract supplies. These spot LNG cargoes became more important for Japan and South Korea after Fukushima aftermath in March 2011 which led to the nuclear plant shutdown. In this case, Japanese gas companies need to pay a premium to secure LNG shipment from other markets in the world. Figure 3 proves that between 2016 to 2017, Japan and South Korea combine as the largest spot buyers in the market.

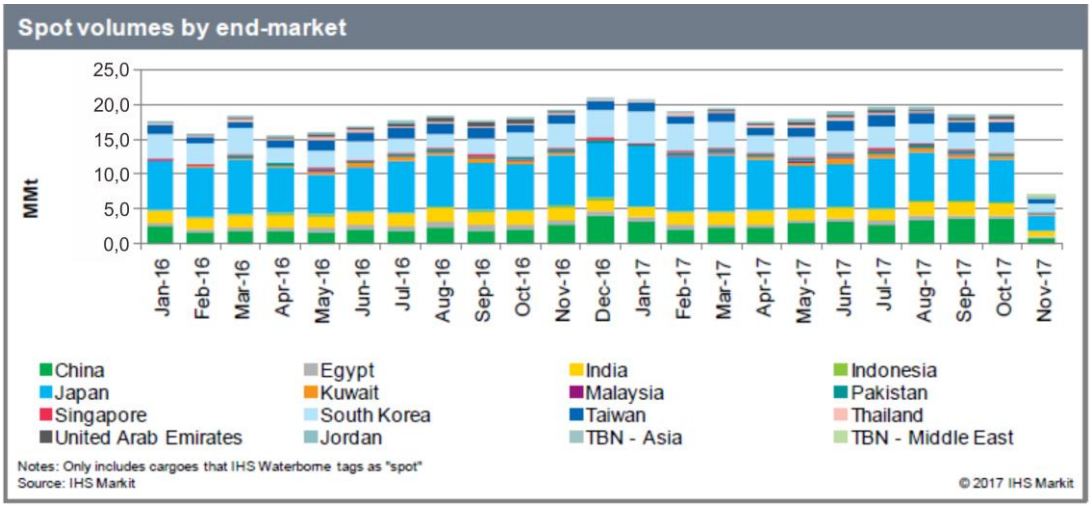

Figure 3: Asia and Middle East LNG spot volumes

However, due to the high price of spot LNG cargoes that Japanese and South Korean companies have to pay as presented in figure 4, they prefer to have LNG price based on long-term contracts. The price structures have to be modified, such as changing the crude oil prices to Henry Hub gas prices, to move away from volatile oil prices. Furthermore, in anticipation of US shale gas revolution, several Japanese trading houses and utilities entered into LNG long-term contract which used Henry Hub gas price indexation from Cameron LNG, Cove Point LNG, and Freeport LNG in 2012, (Miyazaki & Limam, 2013).

These arguments could be the explanation why although Japan and South Korea are attracting many LNG spot cargoes, however, there is no price linkage between Asian LNG spot and Japanese LNG long-term contract prices in the period of 2010 – 2017. The long-term LNG contract will still be the backbone of Japanese and South Korea LNG imports. Japan and South Korea are active in securing

long-term LNG contracts with different price indexation if possible, for example by using Henry Hub gas prices. Furthermore, this study examined the dynamics of these prices in the period of 2010 - 2017, whereas, the spot or short-term LNG cargoes became important to Japanese LNG portfolio after the Fukushima aftermath in 2011. It could be relatively short for the price linkage to be present between these economic variables.

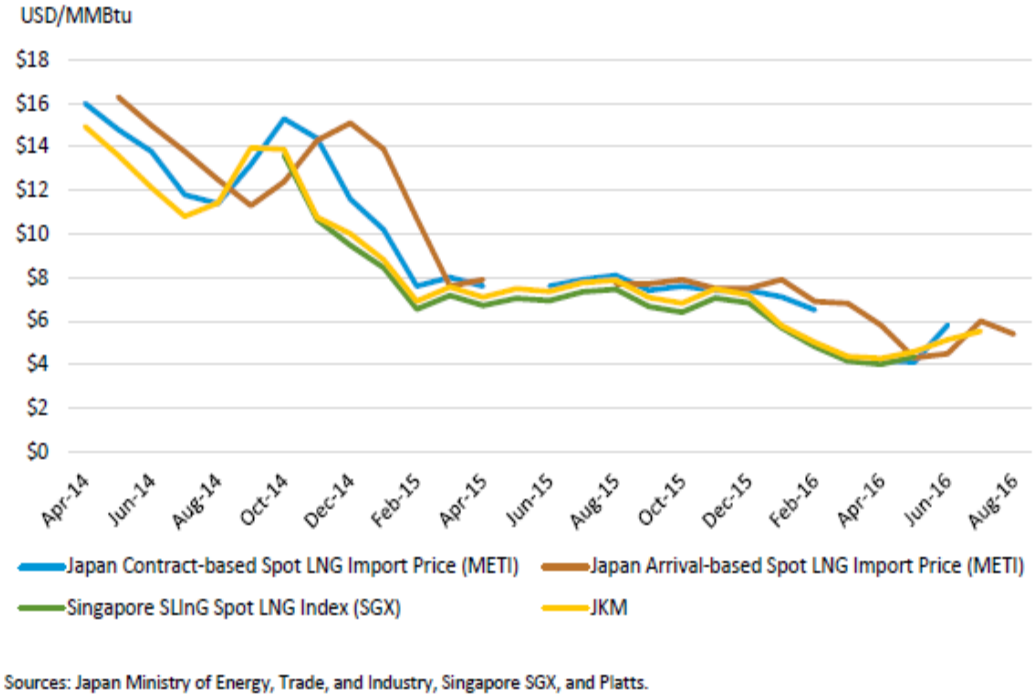

Figure 4: Spot Price Indexed in Asia Pacific 2014 - 2016

Also, the Fukushima aftermath made the LNG market tight in the region and forced the countries in the region to secure many spots or short-term LNG cargoes for their near-term needs.

4.2.2 Taiwan LNG Market

In the previous section, the results indicated that there is a price linkage between Asian LNG spot and its monthly average LNG prices. Because of their major restructuring, Taiwan delayed to conclude new LNG long-term contracts. Thus, Taiwan increased the proportion of mid- and short-term or spot contracts in its LNG supply portfolios to secure uninterrupted energy supplies. Some of the policy taken is Taiwan has diversified its LNG suppliers dramatically in the period between 2002 and 2012. Indonesia and Malaysia made up to 90 percent of Taiwan LNG imports in the 2002 – 2006 periods. This situation changed by 2012, with a mixture of several countries in East Africa and the Middle East. According to Vivoda (2014), Taiwan has been the least active LNG importing countries to secure its supplies, with only one new long-term contract signed with Qatar in 2008.

4.3 General Discussion

So far, the co-integration tests among Asian LNG prices were carried out and some arguments to support the results were presented. The Asian LNG spot prices are not co-integrated with both Japanese and South Korean LNG long-term contract prices. In contrast, Asian LNG spot prices are co-integrated with South Korean LNG a long-term contract prices.

The fact that the monthly average Japanese and South Korean LNG prices do not have the long-run relationship with Asian LNG spot prices is because these countries continued to rely most of their

LNG deliveries on long-term contracts. They might have been trying to diversify their source of LNG cargoes from spot or short-term contracts. However, the results above imply that this change is very slow to materialize at the moment, as they are still importing most of their LNG shipments through the long-term contracts.

4.3.1 Henry-Hub Gas Price Indexation in LNG Contracts

The existence of price linkage for some countries in Asia-Pacific Basin could mean that the market fundamentals in Atlantic Basin have greater influences on their LNG markets. It is quite difficult to justify whether this fact is good or bad at present. Furthermore, the effect of the US shale gas revolution could maintain Henry Hub prices low due to abundant production in the US. LNG customers in Asia would be ready for the fluctuation of Henry Hub price that is included in the LNG price structure, because of decreasing Henry Hub price volatility, (Miyazaki & Limam, 2013). Since some Asian LNG importing countries still want to use the long-term contracts for their LNG deliveries, having a long-term contract with Henry Hub prices embedded in the formula would be an alternative way to reduce the exposure of huge fluctuation of crude oil prices.

4.3.2 Unforeseen Changes in the Crude Oil Prices

When the Brent crude oil prices sustained around US$100/bbl in 2009 – 2014 period, many industry players wanted to have LNG price structure review. However, the effect of US shale gas revolution on international gas pricing should not be neglected. In 2016, the Brent crude prices fell to around US$40/bbl, due to supply glut from the US oil production and an internal competition to secure their market share among OPEC member countries. With significant and sustained price changes of crude oil, it would give a different view of retaining JCC formula in this industry.

4.3.3 Creation of Asian Gas Hub

From the discussion above, it appears that Asian LNG markets are still fragmented, and many governments in Asia have to put much effort to build a more robust Asian LNG pricing mechanism which reflects only the supply and demand dynamics in Asia-Pacific Basin. It becomes apparent that having Asian gas hub, which was devised by IEA, is necessary to reduce other external effects on LNG prices, such as the type of commodity for price indexation and the length of contract terms. The importing LNG countries in Asia could start from restructuring their gas markets to support the creation of gas trading hubs in the region. However, it should be born in mind that Asian gas hub does not guarantee lower prices than crude oil indexation LNG formula. It will lead the markets to price natural gas at its relative value in a specific energy mix.

5. Conclusion

This study has investigated the presence of price linkage among Asian LNG prices. The results show that both historical Japanese and South Korean LNG prices do not have price linkage with Asian LNG spot prices. On the other hand, the historical Taiwanese LNG prices have a long-run relationship with Asian LNG spot prices.

The proportion of LNG long-term contracts still dominates Japanese and South Korean LNG markets. Hence, their monthly averages of LNG prices were not greatly affected by the natural gas market dynamics in the Atlantic Basin. Their price discovery process is not influenced by the LNG spot price. Nonetheless, Taiwanese LNG markets have price linkages with gas markets in Atlantic Basin. The presence of price linkage in Taiwanese LNG markets is expected with the growing number of spot LNG cargoes using trading gas hub price indexed which they secured. It could imply that Taiwanese can use the LNG spot price as reference price during their price discovery process when purchasing the LNG cargoes.

The results above show that Asian LNG markets are not unified, and these facts need serious attention from many governments in Asia to have more robust Asian LNG pricing mechanism which reflects only Asia-Pacific Basin market fundamentals. Creating gas trading hubs could be viewed as a long-term solution to have regional LNG spot price assessments and to move away from the traditional Asian LNG pricing mechanism. Creating gas trading hub in Asia is needed to show the real supply and demand fundamentals in the region. The LNG consumers will pay the prices what they consume. A considerably high Asian LNG spot price in the current situation is due to the transportation cost to ship the spot cargoes and the premium to attract the LNG cargo shipments. The necessity to build Asian gas hub arises to eliminate or reduce these hidden costs. However, there should be enough time to develop a liquid and transparent gas trading hub in Asia, because the market in this region has some physical limitation, such as interconnectedness of the gas networks (Warner, Varro, & Corbeau, 2013). Therefore, many countries could start preparing to restructure their gas markets to support the creation of gas trading hubs in the region in the future.

References

Argenton, M. (2012). *Empirical Identification of Japanese LNG S-Curve Contracts: Cointegration and Structural Breaks*. Chicago, USA: University of Illinois.

Aruga, K. (2013). The U.S. Shale Gas Revolution and Its Effect on International Gas Markets. *MPRA Paper 49545*. Munich, Germany: University Library of Munich.

Aruga, K., Managi, S. (2011). Linkage among the U.S. Energy Futures Markets. *MPRA Paper 36086*. Munich, Germany: University Library of Munich.

Asche, F., Gjolberg, O., Volker, T. (2003). Price Relationships in The Petroleum Market: an Analysis of Crude Oil and Refined Product Prices. *Energy Economics*, 25, pp. 289-301.

Bachmeier, L., Griffin, J.M. (2006). Testing for Market Integration: Crude Oil, Coal, and Natural Gas. *Energy Journal*, 27, pp. 55-71.

BP Statistical Review of World Energy 2013 Workbook. (2013). British Petroleum.

Darrat, A.F. (1998). Tax and Spend, or Spend and Tax? an Inquiry into the Turkish Budgetary Process. *Southern Economic Journal*, 64, 940-956.

Ellis, S. (2013). *Evolution of the spot trade since Fukushima*. ICIS.

Engle, R.F., Granger, C.W.J. (1987). Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*, 55, 2, pp. 251-276.

Flower, A., Liao, J. (2012). *The Pricing of Internationally Traded Gas* (pp. 338-374). England: Oxford Institute for Energy Studies (OIES).

GIIGNL. (2013). *The LNG Industry in 2012*. Accessed in http://www.giignl.org/publications

Goodwin, B.K., Schroeder, T.C. (1991). Cointegration Tests and Spatial Price Linkages in Regional Cattle Markets. *American Journal of Agricultural Economics*, 73, pp. 452-464.

Hartley, P.R., Medlock, K.B., Rosthal, J.E. (2008). The Relationship of Natural Gas to Oil Prices. *Energy Journal*, 29, pp. 47-65.

Higashi, N. (2009). *Natural Gas in China - Market evolution and strategy*. Paris, France: International Energy Agency.

IGU Annual Report and Accounts 2010. (2011). Barcelona, Spain: International Gas Union (IGU).

Johansen, S., Juselius, K. (1990). Maximum Likelihood Estimation and Inference on Cointegration – with Applications to the Demand for Money. *Oxford Bulletin of Economics and Statistics*, 52, pp. 169-210.

Kilian, L. and Murphy, D. (2014) The Role of Inventories and Speculative Trading in the Global Market for Crude Oil. *Journal of Applied Econometrics*, 29, pp. 454-478.

Lin, S. C. (2012). Energy Policy & LNG Supply and Demand in Taiwan. Taiwan: CPC Corporation.

Lutkepohl, H., Saikkonen, P., Trenkler, C. (2000). *Maximum Eigenvalue Versus Trace Tests for the Cointegrating Rank of a VAR Process. Discussion Papers, Interdisciplinary Research Project 373: Quantification and Simulation of Economic Processes.*

Maggiora, D., Skerman, R. (2009). *Johansen Cointegration Analysis of American and European Stock Market Indices: An Empirical Study*. Lund University.

Medlock III, K. (2014). *Natural Gas Price in Asia: What to Expect and What It Means*. Houston: James A. Baker III Institute for Public Policy.

Miyamoto A., Ishiguro, C. (2009). *A New Paradigm for Natural Gas Pricing in Asia: A Perspective on Market Value*. England: Oxford Institute for Energy Studies (OIES).

Miyamoto, A., Ishiguro, C., Yamada, T. (2012). *Irrational LNG Pricing Impedes Development of Asian Natural Gas Markets: A Perspective on Market Value*. Osaka: Osaka Gas.

Miyazaki, K., Limam, M. (2013). *Will LNG Exports from North America / East Africa Drive Global Price Integration?*. New York: Poten & Partners.

Phillips, P.C.B., & Ouliaris, S. (1998). Testing for Cointegration Using Principal Component Methods. *Economics Dynamics and Control*, 12, pp. 205-230.

Rogers, D., White, M., Phua, D. (2014). *Prospects for Development of an Asian LNG Trading Hub*. King & Spalding: Energy Newsletter.

Ssekuma, R. (2011). *A Study of Cointegration Models with Applications*. Zambia: University of Africa.

Stern, J., Rogers, H. (2014). *Challenges to JCC Pricing in Asian LNG Markets*. England: Oxford Institute for Energy Studies (OIES).

Tae-Hoon, A. (2009). Supply and Demand Trends and Plans for Natural Gas in South Korea. Japan: The Institute of Energy Economics.

Vivoda, V. (2014). LNG import diversification in Asia. *Energy Strategy Reviews*, 2, pp. 289-297.

Warner, K., Varro, L., Corbeau, A. (2013). *Developing a Natural Gas Trading Hub in Asia – Obstacles and Opportunities*. Paris, France: International Energy Agency.

Wei W.S. (2006). *Time Series Analysis: Univariate and Multivariate*. Boston: Pearson.

World Energy Outlook 2014: Executive Summary. (2014). Paris, France: International Energy Agency (IEA).

Yule G. U. (1989). Why Do We Sometimes Get Nonsense-Corrections Between Time Series? – A Study In Sampling and the Nature of Time Series. *Royal Statistical Society*, 1, pp. 1-63.