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Price Spillover Effects across Natural gas, Oil and stock markets in Korea, China and Japan

Hong Chong Cho [*], Li Sha[**]

This thesis examines the price spillover effects across natural gas, oil and stock markets on three countries in Asia (Korea, China and Japan) by using a VAR model. LNG is projected to be much important energy recourses in recent years, the consumption is rising. Prior to the 1980s, LNG was imported by Japan and Korea as important energy component, as recently as 2006, China began to important both natural gas and LNG from other countries. Different with the crude oil market, natural gas market is still under development, its demand and consumption has seasonal and geometrically characteristics.

Most of the paper apply linear time series model or nonlinear model to measure dynamic relationship between natural gas and oil, and the relationship between either oil price shocks on stock market or oil price spillover to natural gas market. Sebastian Nick and Stefan Thoenes (2013) use a SVAR approach for modelling the interdependencies between the main gas market fundamentals in order to explicitly examine the relevant transmission channels affecting the natural gas price. Nonlinear model could be used to investigate asymmetric price transmission between energy commodities when unexpected changes arise.

This thesis investigates the empirical relationship among LNG, oil and stock market across through Korea, China and Japan. The results show that Korean and Japanese gas prices are cointegrated with WTI oil prices, but Chinese natural gas market still under early phase of development, it doesn't show the same results compared with Korea and Japan. These results support the price spillover from crude oil markets to LNG market, but a reverse relationship does not exist. Local stock markets do not support the price spillover to LNG market in Korea, China and Japan, but Japanese LNG importing price spillover to the stock market of Japan. The different results of price spillover effect could be explained by the pricing mechanism of LNG.

Key Words: Vector autoregression (VAR), time series model, price spillover, LNG, price mechanism.

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I. INTRODUCTION

1. Background and motivation

International natural gas market has three important regionals: North American (United States), Europe and Asia area (Japan, Korea, and China). Each area has its pricing mechanism, and the common method is link natural gas price with oil. Natural gas and crude oil play the important role as a primary fuel in the residential and commercial market, also they serve as important inputs for industrial production. Natural gas is one of the cleanest and efficient energy resources, it has become a competitive substitute for coal as lower-carbon fuel. Considering the environmental requirements in economic growth, the demand of natural gas is increasing in Asia area.

This thesis investigates the price relationship between the prices of liquefied natural gas (LNG) and crude oil in Asia area. Specifically, I would like to find out how and to what extent price spillover effect in Asia market is influenced by crude oil shocks from international markets. At the same time, this thesis also focus on the topic that to what extent the stock markets have influence on LNG price.

This thesis is motivated by the following main factors. First, as China is in the accelerating stage of urbanization and industrialization, the demand growth of energy leads to the greenhouse gas emission, and the pressure to prevent the atmosphere pollution ask for China to use clean energy which not only satisfied the economic development but also reduce environmental pollution. Natural gas as kind of much more efficient and clean energy than coal gets a lot of attention during the period of energy transformation. Current gas supplement from domestic production is not enough, from 2006, China for the first time received from Australia. Date back to 1968, Japan was the first country in Asian began to import LNG, and Korea imported its first LNG in 1986. These three countries demand the most LNG consumption in Asia market, it is not an easy problem we need to solve that large import quantity without reasonable price.

Second, as LNG trade has three main regional markets: Europe, North American, and Asian (Japan, Korea, China), this regional market has been established due to gas to gas competition, little capability of LNG production or difficult to build pipeline infrastructure. In turn, it implies that each gas market was characterized by specific demand pattern and supply costs. Different from crude oil, LNG market still under development. Asian market usually link LNG price with crude oil index, this price mechanism could not reflect really LNG price thus been charged according to crude oil price changes rather than the LNG supply-demand balance. From October 2014, crude oil price was fell down rapidly, during this special period, the problem whether LNG price has been adjusted or reformed is raised.

Third, according to the law of one price, commodity product should be converge into an equilibrium, but limited to production and consumption, price formation of Asian is not reflected by supply-demand, but rather got much influenced by Middle East and southeast LNG export market. Since Asian premium of crude oil has been known and it is not limited to crude oil but exposed on other energy, this thesis examines how Asian LNG market is affected by oil shocks from international market.

While Asia LNG importing market triggered by high demand and consumption growth, the market also dynamic and is challenging for some reasons, including warmer winter and regional economic slowdown. As Asia countries energy resources supply dependent on importing, crude oil prices has impact on Asian economies and has great impact on LNG importing prices. Crude

oil prices have been rising rapidly after 2000, its price reached to $145/barrel in 2008 and dropped down quickly after financial crisis, and it caused large fluctuation in energy markets and have great shock in developing economies than in developed economies[1]. This thesis seeks to investigate trends in the Asian energy market to find out how oil prices impacted on gas importing price and investigate the relationship between oil price and stock prices of three countries

2. Framework and Organization

This thesis proposes a VAR model that addresses the issue how LNG price in Korea, China and Japan reacts to international oil price and stock market shocks. The objective is to identify the price spillover among LNG, oil and stock markets, investing whether price changes in one market would spillover to the other. LNG markets tend to be geographically segmented, Korea, China, Japan basically involved in the main market of LNG in Asia, by investigating the pricing mechanism of LNG in this region, a comparison of three countries is discussed.

This thesis is organized as follows. In Chapter II, previous studies and LNG pricing mechanism have been discussed. Chapter III describes the data description and methodology. Chapter IV presents a VAR (1) model, as well as granger causality tests. These measures are used to investigate the price spillover effect between each market and presents the results. The concluding remarkets are in Chapter V.

II. LITERATURE REVIEW

1. Theoretical background

The objective of this thesis is to provide estimates of the price spillover effect across natural gas, crude oil and stock market returns in three Asia countries, it will be empirically analyzed whether natural gas and crude oil prices have an equilibrium relationship, and in which situation they appeared to be decoupled.

Most of the paper apply linear time series model to measure dynamic relationship between natural gas and crude oil. Some of the studies attempt to investigate the relationship between either oil price shocks on stock market or oil price spillover to natural gas market.

Lin and Li (2015) test for whether price and volatility in one market transmit in to another market by combining VEC and MGARCH methods, they find that natural gas price in US is decoupled with crude oil price in the long term, but natural gas price is cointegrated with crude oil in japan; the price change in crude oil market would oil market would transmit to the gas market in US, Europe, Japan, but not support the vice versa hypothesis.

1) Hui-Ming Zhu, Rong Li, Sufang Li. 2014. Modelling dynamic dependence between crude oil prices and Asia-Pacific stock market returns. *International review of Economics and Finance.* Vol.29, 208-223.

Hwang and Kim (2012) use VEC method find that there is long-run relationship between crude oil prices and gas prices.

Maxwell and Zhu (2008) analyzed the relationship between U.S. LNG imports, the Henry Hub price of natural gas relative to U.K. and Asia gas prices by employing a non-structural VAR model. It was showed that the U.S. demand for LNG is driven by long-term and seasonal trends in domestic gas consumption and production. U.S. to U.K. and Asian gas price ratios and shipping costs appear to the most important determinants of U.S. LNG imports.

Nick and Thoenes (2013) use a structural VAR to examine the relevant transmission channels affecting the natural gas price. This research results find that natural gas price could be affected by temperature, storage and lack of supply in the short-term, while the natural gas price is linked to crude oil and coal prices in the long-term.

Panagiotidis and Rutledge (2006) examines the relationship between U.K. gas prices and the Brent oil price. The recursive VAR techniques demonstrated that in the highly liberalized U.K. gas market, gas prices and oil prices are moving together in the long-run.

Kouchaksaraei, Movahedizadeh and Mohanmmalikhani (2016) use reduced VAR model investigates the effect of natural gas price on the three leading natural gas exporting countries' stock market (Russia, Norway and Qatar) and find that natural gas prices affected Russia and Norway stock exchange index but natural gas price shock does not have impact on three countries' stock market.

Nonlinear model could be used to investigate asymmetric price transmissions between energy commodities. Nonlinear behavior of economic and financial time series happens when unexpected changes arise (financial crisis, sudden changes in demand and supply, extreme events).

Atil, Lahiani and Nguyen (2012) use a nonlinear autoregressive distributed lags (NARDL) model to examine the pass-through of crude oil prices into gasoline and natural gas prices. This study shows that both gasoline and natural gas prices adjust to changes in the price of oil.

Zhu and Li (2012) use copula models to investigate the dynamic dependence between crude oil prices and stock markets across the Asia-Pacific region and the results show that the dependence between oil prices and stock market returns is generally weak.

This thesis builds on previous literature by combining oil, gas, stock market in a comprehensive framework to estimate the spillover effect between them. First, I apply VAR model to examine the price spillover effect. Second, I apply a Granger Causality test to specify the casual relationship between each two markets.

2. LNG importing price mechanism

In Asian region, Japan was the first country that importing LNG back to 1967. At early time, Japanese LNG importing price was linked to oil producing countries' crude oil prices (government selling price; GSP). At 1980s, since the world crude oil price was fallen down, the

demand of LNG was increasing, the LNG importing price formula changed to peg to Japanese Crude Cocktail (JCC). The formula[2)] is:

$$P_{LNG}(t) = \alpha P_{JCC}(t) + \beta; \quad (1)$$

$P_{LNG}(t)$: LNG importing price, $P_{JCC}(t)$: the price of JCC, α: the slope of crude oil price, β: a constant.

JCC represents Japan's 17 kinds of average crude oil importing prices. In China, there is not similar influential crude oil index, it is not possible to link the LNG importing price with domestic crude oil price of China. Even through China has followed Japan to peg its LNG importing price with Japan, there are a lot of difference between the two countries. First, China has a lot of domestic natural gas resources, and China not only import LNG, but also import pipeline gas from neighboring countries. Japan has to import all of the LNG from abroad. Secondly, LNG market in China is still immature. LNG does not account for very large percentage of energy structure. The market could be adjusted to country's energy plans and could be controlled. But Japan is relatively mature LNG importer. LNG is mainly used for generating electricity.

III. DATA DESCRIPTION AND METHODOLOGY

1. Data description

For the empirical analysis, this paper uses monthly prices of LNG from three major consuming countries in Asian area, namely China (total weighted average delivered price), Korea (LNG import price), Japan (LNG import price, CIF base). The time period of the analysis extends from January 1998 to December 2015, involving 216 observations for Korea and Japan. In 2006, China began to import natural gas from abroad, the time period of the analysis of China involving 108 observations extends from January 2007 to December 2015. The corresponding oil prices are West Texas Intermediate (WTI) is used to represent the world oil market, published by the United States Energy Information Administration. Original crude oil price units are Dollars per Barrel, all prices are converted to be US$/MMBtu (1 barrel of oil crude oil=5.6MMBtu). The stock market prices are as follow: China Shanghai Stock Exchange Composite Index (SSE), South Korea Composite Stock Price index (KOSPI), Japan Nikkei 225 stock Average (NIKKEI), New York Stock Exchange composite index (NYSE). All index data were downloaded from Yahoo Finance.

Table 1 shows the descriptive statistics of LNG importing prices from China, Korea and Japan, crude oil price of WTI and stock price returns from China, Korea, Japan and the United States. Korea and Japan has relative high importing prices than China, and the variance is much larger. As mature LNG importing countries, Korea and Japan has long importing history, the market has been fully conducted. In stock market, Japan and United states as developed countries has smaller variance than emerging countries like China and Korea.

2) 何春蕾，杨鹏程，陈鸿，牛新. 2014. 中国进口天然气价格公式研究. *天然气技术与经济*. Vol.8(4).

<Table 1> Descriptive statistics on energy prices and stock index

	LNG			Crude Oil	Stock Index			
	China	Korea	Japan	WTI	SSE	KOSPI	NIKKEI	NYSE
Obs.	108	216	216	216	216	216	216	216
Mean	7.8213	8.9445	8.7149	10.4456	0.5030	.7643	.1023	10.3447
Max.	13.97	16.76	18.12	23.9071	27.8055	39.4537	12.0889	23.4321
Min.	3.11	2.5	2.72	2.0268	-28.278	-26.3112	-27.2163	1.7946
Std. dev.	3.2450	4.3511	4.7402	5.4818	8.0511	8.1333	5.7947	6.0963
Skewness	-.0352	0.2924	0.5505	0.2439	-.2358	.3826	-.7390	0.3354
Kurtosis	1.6805	1.8032	1.8703	1.8775	4.5326	5.5686	4.4874	1.7584
Variance	10.5301	18.9318	22.4691	30.0510	64.8195	66.1510	33.5789	37.1646

Figure 1 presents the natural gas prices in China, Korea and Japan. As we can observe from the figures, regional LNG price is segmented, and the China LNG import price is deviated from Korea and Japan. Both China and Korea has much more fluctuation than Japan. From 1998 to 2006, LNG importing prices from Korea and Japan are stay at low price and increasing slowly, but from 2007, the importing price increased quickly to the peak in 2009 and drop down sharply to the price similarly with 2007. After that, the importing price are keep increasing until 2015, the prices are keep going down. China importing LNG from 2006, the importing price is quite fluctuated and keep increasing. In 2015, the importing price also went down.

<Figure 1> LNG importing prices

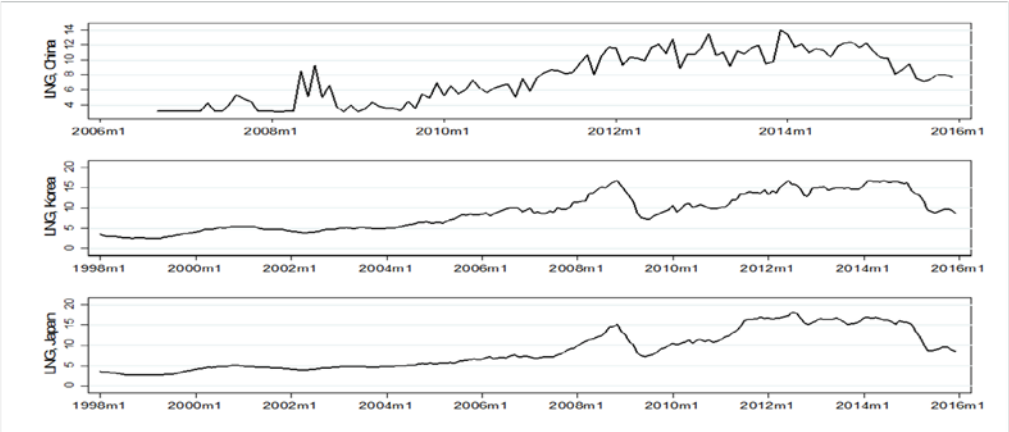


Figure 2 shows all log prices of three countries fluctuate around the mean value, which means they are stationary mean-reverting series. LNG prices of three countries are violent changed after financial crisis lasting from 2008 to 2009, LNG prices of Korea and Japan also dramatic changed from 2015 to 2016 due to fall down of crude oil price.

<Figure 2> First-difference of log prices of LNG

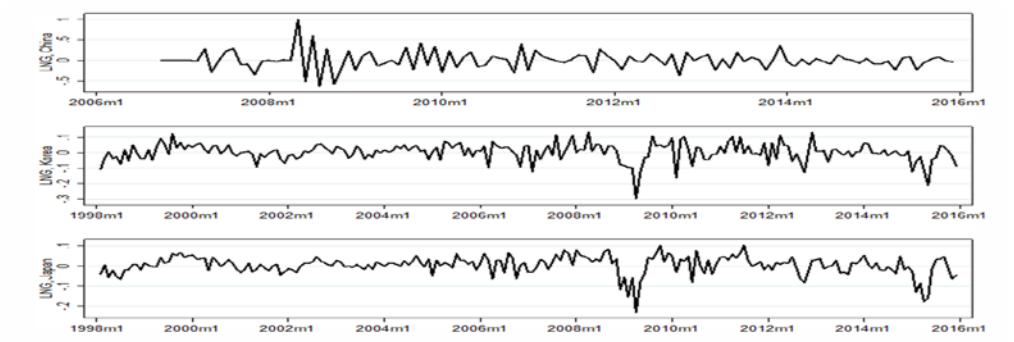


Figure 3 illustrates crude oil price was increased significantly after 2000, and fell down suddenly due to financial crisis. The economy slow down caused decline in the energy demand. After financial crisis, the oil price gradually increased till 2014 and drop sharply because of falling demand.

<Figure 3> Oil price in level and its first-difference of log price

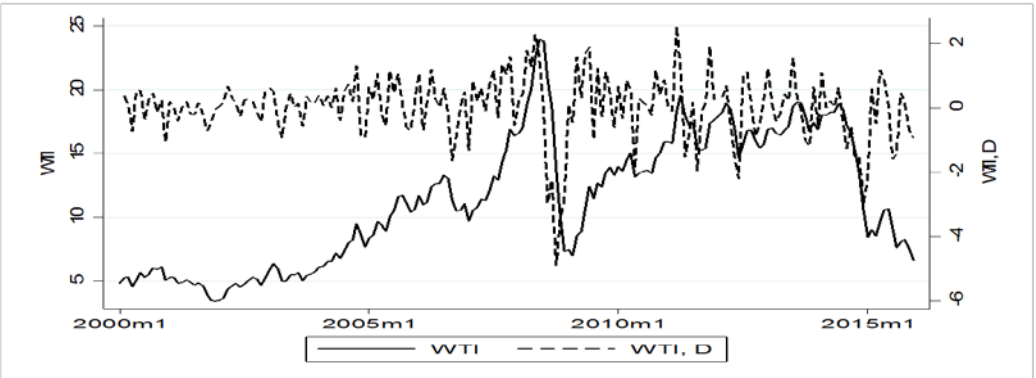
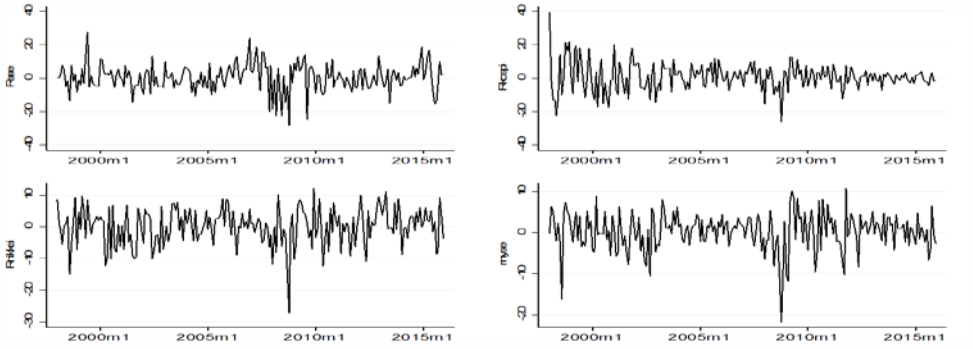


Figure 4 presents the sensitivity to the 2008 financial crisis has been shown in the four countries' stock returns. Japan and U.S stock markets were fluctuated extremely. Korea and China's stock return also changed dramatically from 2008 to 2009. After 2010, stock return change is also volatile, but Korea stock return was not that violent compared with other three countries.

<Figure 4> Stock market returns



As we can observe from above figures, the prices of LNG of Korean and Japan exhibit co-movement, and the co-movement is rather stronger between China and other two countries. The prices of oil and LNG are related, also the stock return and LNG prices seem to be related. There are two main fluctuate change of LNG prices in Korea and Japan, the first is from 2007 to 2009, the LNG prices are increased and decreased sharply, not only LNG prices, but also oil prices and stock returns are fluctuated sharply. This was influenced by global economy. The second time was in 2014, the oil prices went down suddenly, and also, the LNG prices went down in the following time period. It changed with oil prices but had time delay.

2. Stationary properties

Most of the time, the time series are not stationary. Unit root tests are used to test the stationarity and the integration of LNG, oil prices and stock returns. Table 2 presents the outcome of the unit tests in log levels and its first differences, the null hypothesis is that the each series has a unit root. The null hypothesis of having a unit root for all prices in log levels cannot be rejected by both ADF and PP test at 1% level, the null hypotheses that the first difference of each variable has a unit root is rejected at 1% level indicate they are stationary. Thus we accept in log difference, each data series are I (1) processed. DF-GLS shows similar results with ADF and PP. Lags are selected by using AIC, HQIC and SBIC in this thesis rather than optimum lag selected by Ng and Perron. Most of the data series are I (1) process at 1% significant level, Korea data series are I (1) process at 5% significant level. In general, the results suggest that the all variables are stationary at log difference level, allowing the use of Granger causality tests and VAR model.

<Table 2> Unit root test

	ADF		DF-GLS		PP	
	Level	First-difference	Level	First-difference	Level	First-difference
China	-1.803	-5.527***	-1.904	-5.367***	-2.377	-18.315***
Korea	-2.046	-5.622***	-3.010**	-3.138**	-1.542	-11.565***
Japan	-1.691	-6.136***	-2.131**	-4.733***	-1.375	-8.881***
WTI	-2.081	-6.008***	-1.493	-5.130***	-1.868	-10.964***
SSE	-1.918	-5.190***	-2.974**	-5.050***	-1.860	-13.074***
KOSPI	-2.462	-6.636***	-3.069**	-6.314***	-1.472	-12.642***
NIKKEI	-1.929	-5.905***	-1.565	-5.671***	-1.722	-12.821***
NYSE	-1.821	-5.880***	-2.937	-3.597***	-1.746	-12.745***

Note: ***indicate significance at the 1% level. **indicate significance at the 5% level. *indicate significance at the 10% level.

Table 3 to table 5 presents the result of three information criteria: AIC, HQIC and SBIC. These information criteria are based on information theory and are supposed to indicate the relative information lost when the data are fit using different specification. The lag length that produces the minimum value of the information statistic is the preferred specification. According to Lütkepohl (2007) [3], SBIC and HQIC provide consistent estimates of the true lag order, while the AIC overestimate the lag order with positive probability. As we can see from the table, the optimal lag order was marked with asterisk. When the results of three information criteria are different with each other, I choose the minimum value to make sure the information of data was not missed. The results shows that each price of oil, natural and stock is integrated of order one. Thus each model is a VAR (1) model.

3) Helmut Lütkepohl. 2007. *New introduction to multiple time series analysis [M]*. Springer.

Table 3 presents the model under Chinese market, it includes China LNG importing price, Shanghai stock market returns, New York stock exchange returns and WTI price. The lag length for China is relatively short.

<Table 3> Optimal lags under several criterions

Lags	CN- SSE-WTI			CN-NYSE-WTI		
	AIC	HQIC	SBIC	AIC	HQIC	SBIC
0	-4.0034	-3.9723	-3.9266	-5.2733	-5.24223	-5.1966
1	-4.4052	-4.2809*	-4.0983*	-5.7475*	-5.6232*	-5.4406*
2	-4.4149*	-4.1973	-3.8777	-5.6476	-5.4300	-5.1104
3	-4.3541	-4.0433	-3.5867	-5.5875	-5.277	-4.8201
4	-4.4091	-4.0050	-3.4115	-5.5892	-5.1852	-4.5916

Table 4 presents the model under Korean market, it includes Korea LNG importing price, Korea stock market returns, New York stock exchange returns and WTI price. The lag length for Korea is also short.

<Table 4> Optimal lags under several criterions

Lags	KR-KOSPI-WTI			KR-NYSE-WTI		
	AIC	HQIC	SBIC	AIC	HQIC	SBIC
0	-7.2992	-7.2799	-7.2515	-8.2699	-8.2507	-8.2223
1	-7.4660	-7.3889*	-7.2754*	-8.4713	-8.3943*	-8.2807*
2	-7.4462	-7.3114	-7.1126	-8.4759	-8.3410	-8.1423
3	-7.4635	-7.2708	-6.9869	-8.4716	-8.2789	-7.9950
4	-7.5528*	-7.3024	-6.9332	-8.5809*	-8.3305	-7.9614

Table 5 presents the model under Japanese market, it includes Japan LNG importing price, Japan stock market returns, New York stock exchange returns and WTI price. The lag length for Japan is short in SBIC, but it is relatively long in AIC and HQIC.

<Table 5> Optimal lags under several criterions

Lags	JP-NIKKEI-WTI			JP-NYSE-WTI		
	AIC	HQIC	SBIC	AIC	HQIC	SBIC
0	-8.2563	-8.237	-8.2086	-8.7150	-8.6957	-8.6673
1	-8.5969	-8.5198	-8.4063*	-9.0910	-9.0140	-8.9004*
2	-8.6546	-8.51975	-8.321	-9.1606	-9.0257	-8.8270
3	-8.5985	-8.4059	-8.1219	-9.1516	-8.9590	-8.6750
4	-8.9379*	-8.6874*	-8.3183	-9.4872*	-9.2368*	-8.8677

3. Methodology

(1) VAR Model

In order to examine the relationship among LNG importing prices, oil price and stock returns on the three countries, a Vector Autoregressive model (VAR) is employed. This model explains that changes in one particular variable are resulted from changes in its own lags or from changes in other variables and the lag of those variables.

Consider a k-dimensional VAR (p) model,

$$y_t = \phi_0 + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \cdots + \phi_p y_{t-p} + \varepsilon_t \quad (2)$$

where ϕ_0 is a k-dimensional constant vector and ϕ_p are K×K matrices for p>0, $\phi_0 \neq 0$, and ε_t is a sequence of independent and identically distributed (iid) random vector with mean zero and covariance matrix Σ_ε.

According to previously analysis, this thesis employs a VAR (1) Model, it could be written as,

$$y_t = \phi_0 + \phi_1 y_{t-1} + \varepsilon_t, \quad (3)$$

For a three variables model, it can be written as

$$\begin{bmatrix} y_{1t} \\ y_{2t} \\ y_{3t} \end{bmatrix} = \begin{bmatrix} \phi_{10} \\ \phi_{20} \\ \phi_{30} \end{bmatrix} + \begin{bmatrix} \phi_{1,11}\phi_{1,12}\phi_{1,13} \\ \phi_{1,21}\phi_{1,22}\phi_{1,23} \\ \phi_{1,31}\phi_{1,32}\phi_{1,33} \end{bmatrix} \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \\ yz_{3,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix}, \quad (4)$$

or equivalently,

$$y_{1t} = \phi_{10} + \phi_{1,11} y_{1,t-1} + \phi_{1,12} y_{2,t-1} + \phi_{1,13} y_{3,t-1} + \varepsilon_{1t}, \quad (5)$$

$$y_{2t} = \phi_{20} + \phi_{1,21} y_{1,t-1} + \phi_{1,22} y_{2,t-1} + \phi_{1,23} y_{3,t-1} + \varepsilon_{2t}, \quad (6)$$

$$y_{3t} = \phi_{30} + \phi_{1,31} y_{1,t-1} + \phi_{1,32} y_{2,t-1} + \phi_{1,33} y_{3,t-1} + \varepsilon_{3t}, \quad (7)$$

(2) Granger Causality test

The granger causality test is designed to detect the causality direction between the time series. More specifically, granger causality test detects a correlation between the current value of one variable and the past values of another variable. Since the monthly data are stationary, allowing the use of the granger causality test.

Consider a bivariate VAR model with two time series Y_t and X_t

$$\Delta Y_t = \phi_{12} + \sum_{i=1}^{T_{11}} \gamma_{11i} \Delta Y_{t-i} + \sum_{j=1}^{T_{12}} \gamma_{12j} \Delta X_{t-i} + \varepsilon_{12t}, \quad (8)$$

$$\Delta X_t = \phi_{22} + \sum_{i=1}^{T_{21}} \gamma_{21i} \Delta X_{t-i} + \sum_{j=1}^{T_{22}} \gamma_{22j} \Delta Y_{t-j} + \varepsilon_{22t}, \quad (9)$$

where Δ is the difference operator, T is the lag order, ϕ and γ are parameters for estimation, and ε_t is an error term. To test whether the Granger causality runs from X to Y, the null hypothesis is:

$H_0: \gamma_{12j} = 0, j = 1,2,3 \dots \dots n.$

If H_0 is rejected, at least one of β_{12j} is not equal to zero, suggesting that past values of X have significant linear predicative power on current values of Y. It normally suggests that X Granger causes Y (X→Y).

IV. EMPIRICAL RESULTS

This thesis employs a VAR (1) model to investigate the relationship among LNG, oil prices and stock returns of three Asia countries. The result indicates that the changes in oil prices would transmitted to LNG markets in China, Korea and Japan. The coefficients in the following tables reveal that lagged differences of both oil and LNG prices would influence the prices of LNG as the parameters in the gas equation are statistically significant, but oil prices is only impacted by lagged differences of itself. The reason is Japan LNG importing price is fully depended on international oil prices, japan imports 90% crude oil from abroad, when the oil price fluctuated, the price surely spillover to LNG market. Based on the same reason Korea LNG importing price is also affected by international crude oil market, but not affected by stock market. It seems like Japan LNG price has related with japan stock market. It consistently with the assumption that oil price spillover to LNG price, but gas price cannot spillover to oil price. Local (China, Korea, Japan) stock market will not be affected by international oil price. But in U.S., NYSE and WTI are affected by each other.

Table 6 presents the results of Chinese market. Both China and US. Stock market has no significant impact on Chinese LNG importing price, and oil price cannot spillover to LNG importing price in China. But US. Stock market has relationship with oil prices.

<Table 6> Estimation results of China

Equation	**Δcn**	**Δsse**	**Δwti**	**Equation**	**Δcn**	**Δnyse**	**Δwti**
$\mathbf{\Delta cn_{t-1}}$	-.5475*** (.0835)	-.0683* (.0401)	.0139 (.0386)	$\mathbf{\Delta cn_{t-1}}$	-.5391*** (.0832)	-.0068 (.0213)	.0136 (.0371)
$\mathbf{\Delta sse_{t-1}}$	.2418 (.2013)	.1026 (.0965)	.0795 (.0931)	$\mathbf{\Delta nyse_{t-1}}$	.4005 (.3878)	.0771 (.0994)	.5048*** (.1728)
$\mathbf{\Delta wti_{t-1}}$	.31213 (.1951)	.1091 (.0936)	.4021*** (.0902)	$\mathbf{\Delta wti_{t-1}}$	.2604 (.2084)	.1518*** (.0534)	.3123 *** (.0929)
constant	.0134 (.0181)	.0026 (.0087)	-.0037 (.0084)	**constant**	.0132 (.0181)	.0013 (.0046)	-.0043 (.0081)

Table 7 presents the results of Korean market. Both Korea and US. Stock market has no significant impact on Chinese LNG importing price, but oil price can spillover to LNG importing price in Korea.

<Table 7> Estimation results of Korea

Equation	Δkr	Δkospi	Δwti	Equation	Δkr	Δnyse	Δwti
Δkr_{t-1}	.2485*** (.0644)	-.0756 (.0927)	-.1131 (.1027)	Δkr_{t-1}	.2434*** (.0643)	-.0720 (.0544)	-.0920 (.1015)
$\Delta kospi_{t-1}$	-.0260 (.0483)	.1549** (.0695)	.1087 (.0771)	$\Delta nyse_{t-1}$	-.0835 (.0812)	.1033 (.0686)	.3487*** (.1281)
Δwti_{t-1}	.1635*** (.0420)	-.0799 (.0603)	.2563*** (.0669)	Δwti_{t-1}	.1662*** (.0152)	.0584* (.0352)	.2451*** (.0656)
constant	.0030 (.0036)	.0057 (.0052)	.0027 (.0058)	constant	.0031 (.0036)	.0024 (.0031)	.0022 (.0057)

Table 8 presents the results of Japanese market. Japan Stock market has no significant impact on Japanese LNG importing price, but U.S. stock market returns has influence on lagged Japanese LNG importing price, and oil price can spillover to LNG importing price in Japan.

<Table 8> Estimation results of Japan

Equation	Δjapan	Δnikkei	Δwti	Equation	Δjapan	Δnyse	Δwti
Δjp_{t-1}	.4792*** (.0594)	-.1938** (.0870)	-.1603 (.1292)	Δjp_{t-1}	.4852*** (.0589)	-.1118* (.0677)	-.1519 (.1265)
$\Delta nikkei_{t-1}$	-.0175 (.0473)	.0987 (.0693)	.1465 (.1029)	$\Delta nyse_{t-1}$	.01920 (.0593)	.1046* (.0681)	.3494*** (.1272)
Δwti_{t-1}	.1005*** (.0307)	.0274 (.0449)	.2556*** (.0667)	Δwti_{t-1}	.0967*** (.0305)	.0573 (.0351)	.2438*** (.0655)
constant	.0018 (.0027)	.0012 (.0039)	.0034 (.0058)	constant	.0017 (.0027)	.0026 (.0031)	.0024 (.0057)

The results of Granger causality test shown in table 9 reveals that there exists causal relationship between oil prices and Japan/Korea LNG markets. In contract, WTI is found no causal relationship with China LNG market. At the same time, New York stock market has no causal relationship with LNG market in these three countries. Based on Monk (1989)'s studies, he found that oil price increases had a greater influence on a country's macro economy than oil price decreases did. When we analysis the question that how does stock markets respond to changes in the price of oil, it could be explained by different situation. "In theory, oil price shocks can adversely affect stock prices through the discount rate channel as monetary policy makers tend to raise interest rates in anticipation of the higher inflation triggered by higher oil prices." One of the possible explanation explained by Abhyankar (2013)[4] gives the insight of the reason why Japan LNG importing price could granger cause the Japanese stock market. Since granger causality test could only give the causality direction test between the time series, further research

[4] Abhay Abhyankar, Bing Xu, Jiayue Wang. 2013. Oil price shocks and the stock Market: Evidence from Japan. *The Energy Journal.* Vol.34, 199-222.

need to be done to find out the relationship between LNG importing prices and stock market returns.

<Table 9> Results of Granger causality test

Bi-variate causation	F-value	P-value	Causality
WTI Granger cause KR	15.183	0.000***	YES
JP Granger cause NIKKEI	4.9639	0.026 **	YES
WTI Granger cause JP	10.734	0.001***	YES
SSE does not Granger cause CN	1.4431	0.230	NO
CN does not Granger cause SSE	2.9097	0.088	NO
WTI does not Granger cause CN	2.5596	0.110	NO
CN does not Granger cause WTI	.1303	0.718	NO
NYSE does not Granger cause CN	1.0666	0.302	NO
CN does not Granger cause NYSE	.1029	0.748	NO
KOSPI does not Granger cause KR	.2889	0.591	NO
KR does not Granger cause KOSPI	.6668	0.414	NO
KR does not Granger cause WTI	1.2118	0.271	NO
NYSE does not Granger cause KR	1.0564	0.304	NO
KR does not Granger cause NYSE	1.7569	0.185	NO
NIKKEI does not Granger cause JP	.13674	0.712	NO
JP does not Granger cause WTI	1.54	0.215	NO
NYSE does not Granger cause JP	.1049	0.746	NO
JP does not Granger cause NYSE	2.7281	0.099	NO

Note: ***indicate significance at the 1% level. **indicate significance at the 5% level. *indicate significance at the 10% level.

While LNG is expected to play an important role in the energy portfolio over both the short- and a medium-to-long term, Korea and Japan has some challenges to tackle for its expansion of natural gas consumption. One of such challenges is the Asian premium problem for LNG prices. The factors behind price gas mentioned above may include differences in the LNG pricing methods and market (supply and demand) environments. In Asian region, the LNG import prices are linked to crude oil import prices of Japan under long-term LNG import contracts accounting for most of LNG supply. LNG prices thus move according to crude oil price changes rather than the LNG supply-demand balance. In recent years, under a lot of changes of political and economic environment, LNG import prices have stayed high. Different from Korea and Japan, China imports pipeline and LNG almost equally, the price mechanism which linked LNG price with crude oil price is not as significant as Korea and Japan, on one side, LNG importing quantity was not as large as other two countries, China importing contracts are begin at 2006, gas accounts 3 percent of Chinese consumption at early time, but China plans to increase amount of gas consumption, the vast majority of increased consumption must come from abroad. Thus reasonable pricing mechanism is important.

V. CONCLUSIONS

This paper explored the spillover effects between crude oil markets and LNG markets, also considered how LNG and oil prices are affected by stock market. At the same time, natural gas

prices in China, Korea and Japan and international oil prices are investigated taking consideration of their pricing mechanism.

By using VAR model, this paper provides evidence that Korean and Japanese gas prices are cointegrated with WTI oil prices. This might be explained by the following factors: Korean and Japanese gas prices are indexed to crude oil price, while natural gas price in the China is determined by policy decisions and negotiation; and based on the results of the granger causality analysis, the analysis supports the presence of price spillover from crude oil markets to natural gas markets, but the reverse relationship does not exist. This is an expected result since natural gas and oil are substitutes in consumption and complements and rivals in production. The segmented regional natural gas markets might not be able to drive the price changes in global oil market due to the relative size of each market.

Due to regional segmentation and limited inter-continental natural gas trade, it is highly possible for each region to have different spillover effects. The results of this paper have at least two policy implications. First, in Korea and Japan which has liberalized gas market in Asian region and their long history of importing LNG, gas prices are oil-indexed, which indicates that the "Asian price premium" of crude oil would spillover to natural gas prices, For example, after 2008 the natural gas prices of Japan are higher than European levels and multiples of North America's. It is thus necessary for Japan (and East Asia) to liberalize the market accompanied by getting more diversified suppliers and developing hubs. Second, the natural gas market in China is still under the early phase of liberalization. The buyers purchase the "Take or Pay" quantity within a contract year through long term oil-indexed contract. Chinese buyers had to pay for much higher oil-related prices of natural gas than spot prices when the latter has sharply dropped, such as in the post-2008 periods. Moving to a more liberalized gas market, it is necessary to enforce new contract mechanisms such as non-dedicated or short-term contracts. In summary, a more liberalized gas market might benefit consumers by preventing unreasonable high natural gas prices.

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Price Spillover Effects across Natural gas, Oil and Stock Markets in Korea, China and Japan

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