41st IAEE International Conference Groningen, 10 Jun. – 13 Jun. 2018

A Strategy of LNG Exporting Countries for Trading in the Northeast Asian Region: Oligopolistic Structures in Spot and Long-term Tradings

11 June, 2018

Presenter: Gobong Choi (gchoi0322@snu.ac.kr)

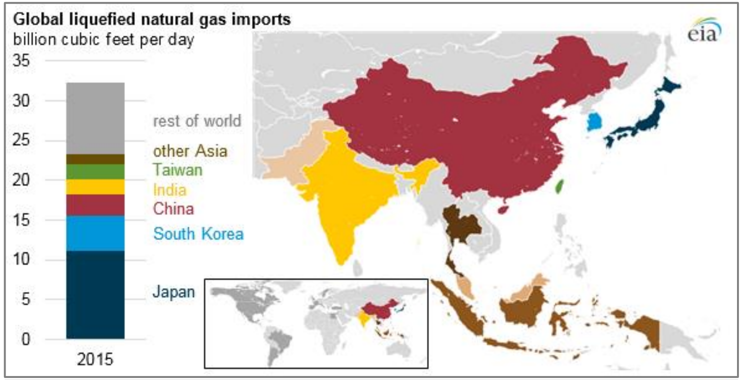
Gobong Choi & Eunnyeong Heo
Seoul National University, Rep. of Korea

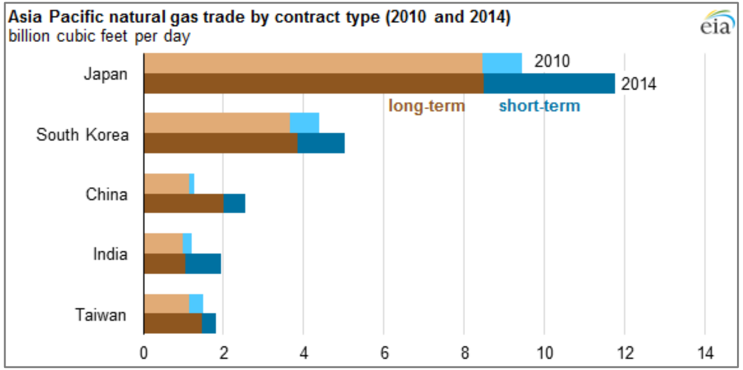
By the Brain Korea 21 PLUS Project (No. 21A20130012821)

Contents

1. Background

Background





- **The Northeast Asia is the heart of LNG trade**
  - In 2016, LNG import volume of Japan, Korea, China, and Taiwan accounted for 31.6%, 13.0%, 10.4%, and 7.2% of the world LNG import volume, respectively

- **Some characteristics in trade environments**
  1) Most of LNG has traded as a long-term contract
     ; The ratio of short-term contracts and spot trades is increasing
  2) There is no competitive trading hub in Asia

- **Questions on the long-term trades; is it competitive?**

- **Questions on the short-term and spot trades ; is it competitive in the presence of long-term contracts?**
  - Anti-competitive: Liski and Montero(2006)
  - Pro-competitive : Allaz(1992), Allaz and Vila(1993)

Source: EIA

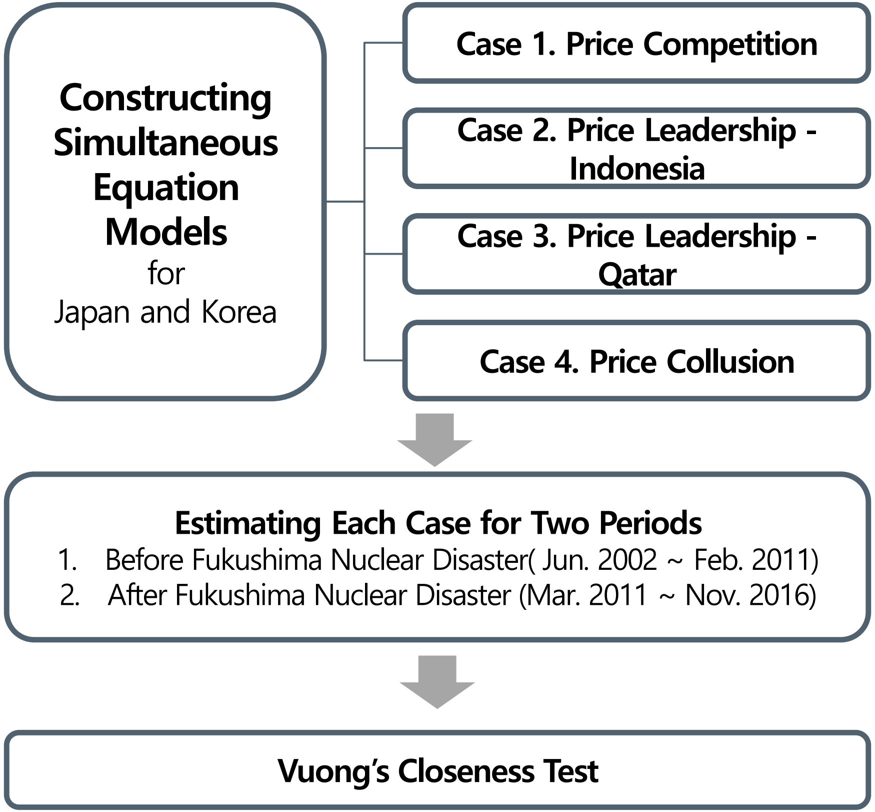
2. Research Framework

Research Question

- How have major LNG exporters determined spot and long-term prices in Northeast Asia?
- Have they determined the LNG spot and long-term prices *competitively?* or *collusively?*

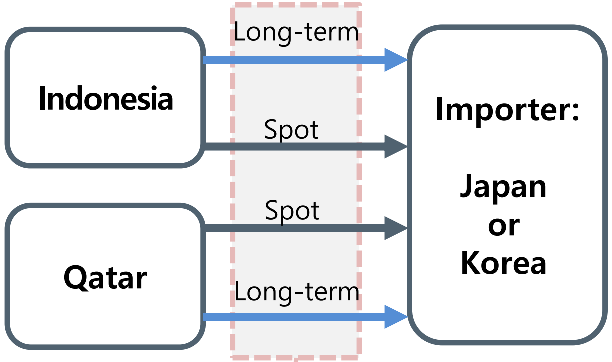
The Main Objectives

- Building simultaneous equation models that can describe the LNG trade in Northeast Asia using the LNG prices as strategic variables
- Finding how the pricing strategy of LNG exporting countries has changed



1. Basic Assumptions and Settings

Assumptions and Settings



- Case 1: Price Competition (Duopolistic)
- Case 2: Price Leadership – Indonesia
- Case 3: Price Leadership – Qatar
- Case 4: Price Collusion

4 cases in spot trades X 4 cases in L.T. trades
= 16 cases

- **1-Importer, 2-Exporters: Duopolistic model**
  - Importers: Japan OR Korea
  - Exporters: Indonesia AND Qatar
- **Strategic Variables: LNG prices**
  - It might be expected that there would be price competition for commodities which can be stored at relatively low cost (e.g. rice, wheat, and coal) (Carter and MacLaren, 1997)
  - Long-term contract prices and spot prices were used as decision variables
- **Price Determination**
  1) Spot: Maximizing the profit of the exporting country
  2) Long-term: Maximizing the joint profit between the importer's risk-averse expected utility and exporter's risk-averse expected profit

2. The Form of Simultaneous Equations

Simultaneous Equations

- **For Japan and Korea, the simultaneous equations models can be constructed which consist of**
  2 – demand functions
  2 – F.O.C.s of the profit maximization problems for pricing the spot volume
  2 – F.O.C.s of the joint profit maximization problems for re-negotiating the long-term contract prices

<Equations>

The general form of the simultaneous equations model
Constraints associated with a particular case are imposed on the parameter matrix and vector

$$\begin{bmatrix} A1 & A2 & A3 & A4 & A5 & A6 \\ B1 & B2 & B3 & B4 & B5 & B6 \\ C1 & C2 & C3 & C4 & C5 & C6 \\ D1 & D2 & D3 & D4 & D5 & D6 \\ E1 & E2 & E3 & E4 & E5 & E6 \\ F1 & F2 & F3 & F4 & F5 & F6 \end{bmatrix} \begin{bmatrix} q^s_{Indonesia} \\ q^s_{Qatar} \\ P^s_{Indonesia} \\ P^s_{Qatar} \\ P^f_{Indonesia} \\ P^f_{Qatar} \end{bmatrix} + \begin{bmatrix} A0 \\ B0 \\ C0 \\ D0 \\ E0 \\ F0 \end{bmatrix} = \begin{bmatrix} u1 \\ u2 \\ u3 \\ u4 \\ u5 \\ u6 \end{bmatrix}$$

Demand Functions

F.O.C.s of Spot pricing (4 cases)

F.O.C.s of Re-negotiating (4 cases)

3. Basic Functions

Functions

- **Importer's Spot LNG Demands (Eq. 1)**
  - A simple linear form of spot and long-term contract prices
  - The long-term contract volumes are pre-determined
- **Importer's Expected Utility (Eq. 3)**
  - Risk-averse expected utility of mean-variance form; Risk-aversion on the long-term contract prices
- **Exporter's Profits (Eq. 2)**
  - Including a simple cost function (a constant marginal cost)
  - The long-term contract volumes are pre-determined
- **Exporter's Expected Profit (Eq. 4)**
  - Risk-averse expected profit of mean-variance form; Risk-aversion on the long-term contract prices

<Equations>

$$q_i^s = \alpha_i + \beta_{1,i}P_{IND}^s + \beta_{2,i}P_{QAT}^s + \gamma_{1,i}P_{IND}^f + \gamma_{2,i}P_{QAT}^f + \delta_{1,i}INC + \delta_{2,i}DUM_{summer} + \delta_{3,i}DUM_{winter} \quad (1)$$

$$\Pi_i = P_i^s q_i^s + P_i^f q_i^f - c_i(q_i^f + q_i^s) \quad (2)$$

$$EU_i = E\left[\left(P_i^s - P_i^f\right)q_i^f\right] - \frac{\theta_i^{IMP}}{2} var\left[\left(P_i^s - P_i^f\right)q_i^f\right] \quad (3)$$

$$E\Pi_i = E(\Pi_i) - \frac{\theta_i^{EXP}}{2} var(\Pi_i) \quad (4) \qquad \forall\, i = Indonesia, Qatar$$

where 1) INC denotes a income variable

2) DUM_{summer} and DUM_{winter} denote seasonal dummies for summer (Jun., Jul., Aug.) and winter (Dec., Jan., Feb.), respectively

3) θ_i^{IMP} and θ_i^{EXP} are risk-aversion coefficients of importer and exporters, respectively

3. Spot Trade - Case 1: Price Competition (Duopolistic)

Maximization Problem

- **Indonesia and Qatar determine their spot prices by solving the profit maximization problems *at the same time***
  - Differentiating the each profit function (Eq. 2) by the each spot price

<Equations>

For Indonesia,

$$\frac{\partial \Pi_{IND}}{\partial P_{IND}^{s}} = q_{IND}^{s} + P_{IND}^{s} \frac{\partial q_{IND}^{s}}{\partial P_{IND}^{s}} - c_{IND} \frac{\partial q_{IND}^{s}}{\partial P_{IND}^{s}} = 0 \quad \leftrightarrow \quad q_{IND}^{s} + \beta_{1,IND} P_{IND}^{s} - c_{IND}\beta_{1,IND} = 0 \qquad (5)$$

For Qatar,

$$\frac{\partial \Pi_{QAT}}{\partial P_{QAT}^{s}} = q_{QAT}^{s} + P_{QAT}^{s} \frac{\partial q_{QAT}^{s}}{\partial P_{QAT}^{s}} - c_{QAT} \frac{\partial q_{QAT}^{s}}{\partial P_{QAT}^{s}} = 0 \quad \leftrightarrow \quad q_{QAT}^{s} + \beta_{2,QAT} P_{QAT}^{s} - c_{QAT}\beta_{2,QAT} = 0 \qquad (6)$$

3. Spot Trade - Case 2: Price Leadership - Indonesia

Maximization Problem

- **Indonesia determines its spot price by solving the profit maximization problems knowing the reaction function of Qatar**
  - Differentiating the profit function of Indonesia considering the change of the Qatar's spot price caused by the change of its own price
  - Qatar determines its spot price by the same way of Case 1; price competition

<Equations>

For Indonesia,

$$\frac{\partial \Pi_{IND}}{\partial P^s_{IND}} = q^s_{IND} + P^s_{IND}\frac{\partial q^s_{IND}}{\partial P^s_{IND}} - c_{IND}\frac{\partial q^s_{IND}}{\partial P^s_{IND}} = 0 \quad \leftrightarrow \quad q^s_{IND} + (\beta_{1,IND} + \beta_{2,IND}\frac{\partial P^s_{QAT}}{\partial P^s_{IND}})P^s_{IND} - c_{IND}(\beta_{1,IND} + \beta_{2,IND}\frac{\partial P^s_{QAT}}{\partial P^s_{IND}}) = 0 \tag{7}$$

For Qatar,

$$\frac{\partial \Pi_{QAT}}{\partial P^s_{QAT}} = q^s_{QAT} + P^s_{QAT}\frac{\partial q^s_{QAT}}{\partial P^s_{QAT}} - c_{QAT}\frac{\partial q^s_{QAT}}{\partial P^s_{QAT}} = 0 \quad \leftrightarrow \quad q^s_{QAT} + \beta_{2,QAT}P^s_{QAT} - c_{QAT}\beta_{2,QAT} = 0 \quad \text{and} \quad \frac{\partial P^s_{QAT}}{\partial P^s_{IND}} = -\frac{\beta_{1,QAT}}{\beta_{2,QAT}} \tag{8}$$

3. Spot Trade - Case 3: Price Leadership - Qatar

Maximization Problem

- **Qatar determines its spot price by solving the profit maximization problems knowing the reaction function of Indonesia**
  - Differentiating the profit function of Qatar considering the change of the Indonesia's spot price caused by the change of its own price
  - Indonesia determines its spot price by the same way of Case 1; price competition

<Equations>

For Indonesia,

$$\frac{\partial \Pi_{IND}}{\partial P_{IND}^{s}} = q_{IND}^{s} + P_{IND}^{s}\frac{\partial q_{IND}^{s}}{\partial P_{IND}^{s}} - c_{IND}\frac{\partial q_{IND}^{s}}{\partial P_{IND}^{s}} = 0 \quad \leftrightarrow \quad q_{IND}^{s} + \beta_{1,IND}P_{IND}^{s} - c_{IND}\beta_{1,IND} = 0 \ \text{ and } \ \frac{\partial P_{IND}^{s}}{\partial P_{QAT}^{S}} = -\frac{\beta_{2,IND}}{\beta_{1,IND}} \tag{9}$$

For Qatar,

$$\frac{\partial \Pi_{QAT}}{\partial P_{QAT}^{s}} = q_{QAT}^{s} + P_{QAT}^{s}\frac{\partial q_{QAT}^{s}}{\partial P_{QAT}^{s}} - c_{QAT}\frac{\partial q_{QAT}^{s}}{\partial P_{QAT}^{s}} = 0 \quad \leftrightarrow \quad q_{QAT}^{s} + (\beta_{2,QAT} + \beta_{1,QAT}\frac{\partial P_{IND}^{s}}{\partial P_{QAT}^{S}})P_{QAT}^{s} - c_{QAT}(\beta_{2,QAT} + \beta_{1,QAT}\frac{\partial P_{IND}^{s}}{\partial P_{QAT}^{S}}) = 0 \tag{10}$$

3. Spot Trade - Case 4: Price Collusion

Maximization Problem

- **Indonesia and Qatar determine their spot prices by maximizing their joint profit function**
  - Joint profit: the weighted sum of Indonesian and Qatari profits
  - Differentiating the joint profit function by the each spot price

<Equations>

Define the joint profit function between Indonesia and Qatar, Π^J

$$\Pi^J \equiv \lambda_s \Pi_{IND} + (1-\lambda_s)\Pi_{QAT} \quad (11)$$

where λ *is a weight for the profit of Indonesia,* $0 < \lambda < 1$

For Indonesia

$$\frac{\partial \Pi^J}{\partial P^s_{IND}} = \lambda_s \frac{\partial \Pi_{IND}}{\partial P^s_{IND}} + (1-\lambda_s)\frac{\partial \Pi_{QAT}}{\partial P^s_{IND}} = \lambda_s\left(q^s_{IND} + \beta_{1,IND}P^s_{IND} - c_{IND}\beta_{1,IND}\right) + (1-\lambda_s)\left(\beta_{1,QAT}P^s_{QAT} - c_{QAT}\beta_{1,QAT}\right) = 0 \quad (12)$$

For Qatar

$$\frac{\partial \Pi^J}{\partial P^s_{QAT}} = \lambda_s \frac{\partial \Pi_{IND}}{\partial P^s_{QAT}} + (1-\lambda_s)\frac{\partial \Pi_{QAT}}{\partial P^s_{QAT}} = \lambda_s\left(\beta_{2,IND}P^s_{IND} - c_{IND}\beta_{2,IND}\right) + (1-\lambda_s)\left(q^s_{QAT} + \beta_{2,QAT}P^s_{QAT} - c_{QAT}\beta_{2,QAT}\right) = 0 \quad (13)$$

4. Long-term contract

Maximization Problem

- **An Importer and an exporter re-negotiate their long-term contract price by maximizing their joint profit function every three months**
  - Joint profit: the weighted sum of risk averse expected utility of an importer (Eq. 3) & risk averse expected profit of an exporter (Eq. 4) for three months
  - Differentiating the joint profit by the **slope term(A)** and **intercept term(B)** of the long-term contract price formula $P_i^f = A_i P_i^C + B_i$

<Equations>

Define the joint profit,

$$\Pi_i^f \equiv (1-\mu_i)\left[r^{imp} EU_{i,1} + \left(r^{imp}\right)^2 EU_{i,2} + \left(r^{imp}\right)^3 EU_{i,3}\right] + \mu_i\left[r^{exp} E\Pi_{i,1} + (r^{exp})^2 E\Pi_{i,2} + (r^{exp})^3 E\Pi_{i,3}\right] \quad (14)$$

where μ_i *is a weight for the expected profit of the exporter,* $0 < \mu_i < 1$

Assuming that the discount factors, r^{imp} *and* r^{exp}*, equal 1*

$$\partial \Pi_i^f / \partial A_i = \omega_1 A_i + \omega_2 B_i = 0 \qquad A_i = f_A(q_i^f, c_i, parameters)$$

$$\partial \Pi_i^f / \partial B_i = \omega_3 A_i + \omega_4 B_i = 0 \qquad B_i = f_B(q_i^f, c_i, parameters)$$

$$\Rightarrow P_i^f = f_A(\cdot) P_i^C + f_b(\cdot) \quad (15)$$

$$\forall\, i = Indonesia, Qatar$$

4. Long-term contract

<Equations>

Main differences when differentiating the expected profit function

- **Case 1: Price Competition (duopolistic)**

$$\frac{\partial P^f_{IND}}{\partial A_{QAT}}, \frac{\partial P^f_{IND}}{\partial B_{QAT}} = 0 \qquad \frac{\partial P^f_{QAT}}{\partial A_{IND}}, \frac{\partial P^f_{QAT}}{\partial B_{IND}} = 0$$

- **Case 2: Price Leadership - Indonesia**
  - Knowing the reaction function of Qatar

$$\frac{\partial P^f_{IND}}{\partial A_{QAT}}, \frac{\partial P^f_{IND}}{\partial B_{QAT}} = 0 \qquad \frac{\partial P^f_{QAT}}{\partial A_{IND}}, \frac{\partial P^f_{QAT}}{\partial B_{IND}} \neq 0$$

- **Case 3: Price Leadership - Qatar**
  - Knowing the reaction function of Indonesia

$$\frac{\partial P^f_{IND}}{\partial A_{QAT}}, \frac{\partial P^f_{IND}}{\partial B_{QAT}} \neq 0 \qquad \frac{\partial P^f_{QAT}}{\partial A_{IND}}, \frac{\partial P^f_{QAT}}{\partial B_{IND}} = 0$$

- **Case 4: Price Collusion**
  - Define Joint expected profit function of the exporters
  - Using Joint expected profit function when solving the problems.

$$E\Pi^J \equiv \lambda_F E\Pi_{IND} + (1 - \lambda_F) E\Pi_{QAT}$$

1. Generating and Handling Data

LNG Volumes

- **The long-term contract volumes: Based on the annual report of the International Group of LNG Importers**
  - Assuming that the annual contract volume is constantly imported every month
- **The Spot volumes: Subtracting the long-term contract volumes from the customs data**

LNG Prices

- **Constructing a simple state-space model, Monthly LNG long-term and spot prices are estimated by Kalman Filter**

<Equations>

Observation Equation:

$$P_{t,customs} = \frac{spot\ volume_t}{total\ volume_t} P_{t,spot} + \frac{longterm\ volume_t}{total\ volume_t} P_{t,longterm} + \varepsilon_t \qquad (25)$$

State Equation:

$$P_{t,spot} = \rho_1 P_{t-1,spot} + \nu_{1,t} \qquad (26)$$

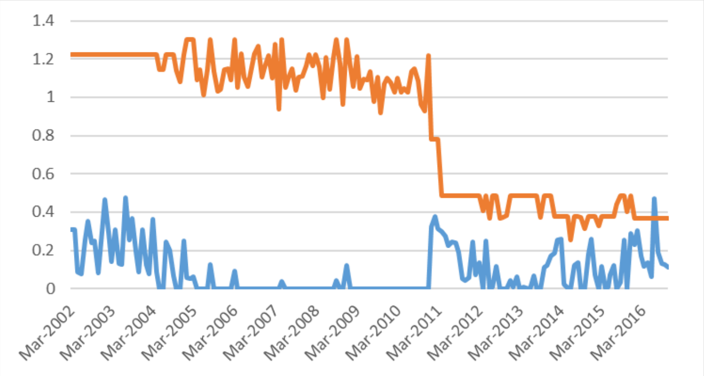
$$P_{t,longterm} = \rho_2 P_{t-1,longterm} + \nu_{2,t} \qquad (27)$$

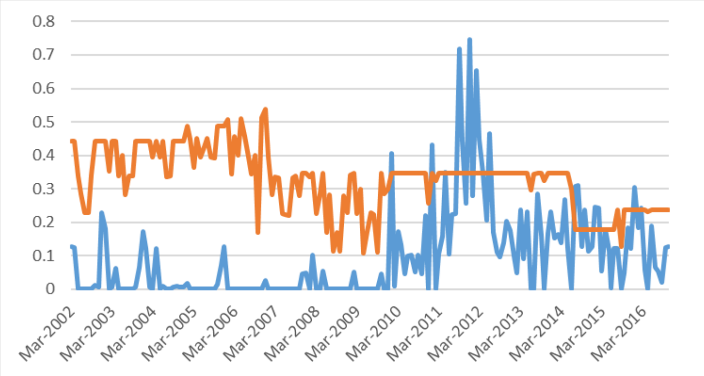
1. Generating and Handling Data

Japan LNG Volume (millions ton)

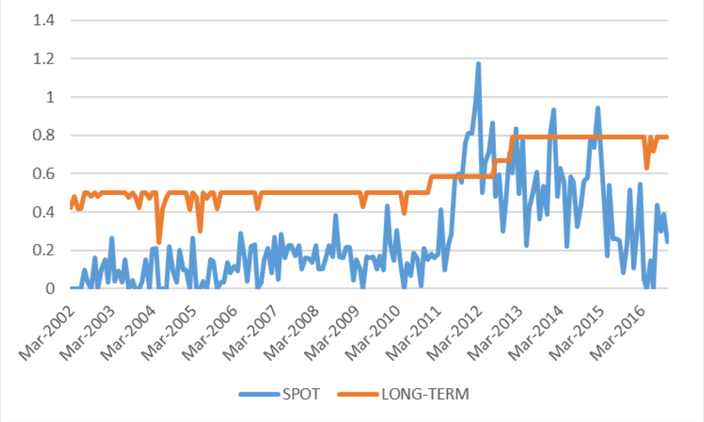
Korea LNG Volume (millions ton)

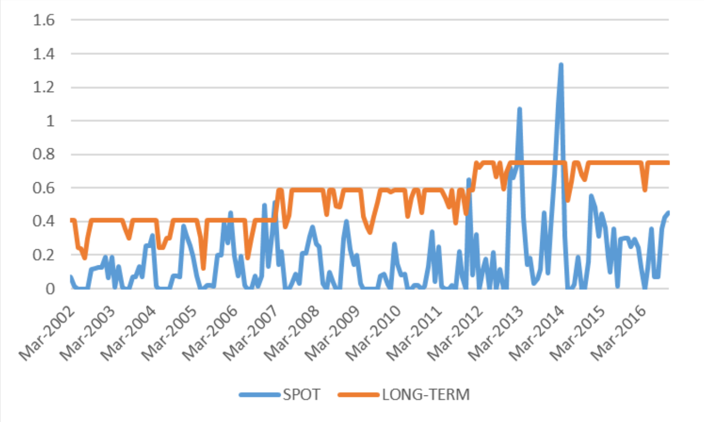
Indonesia





Qatar





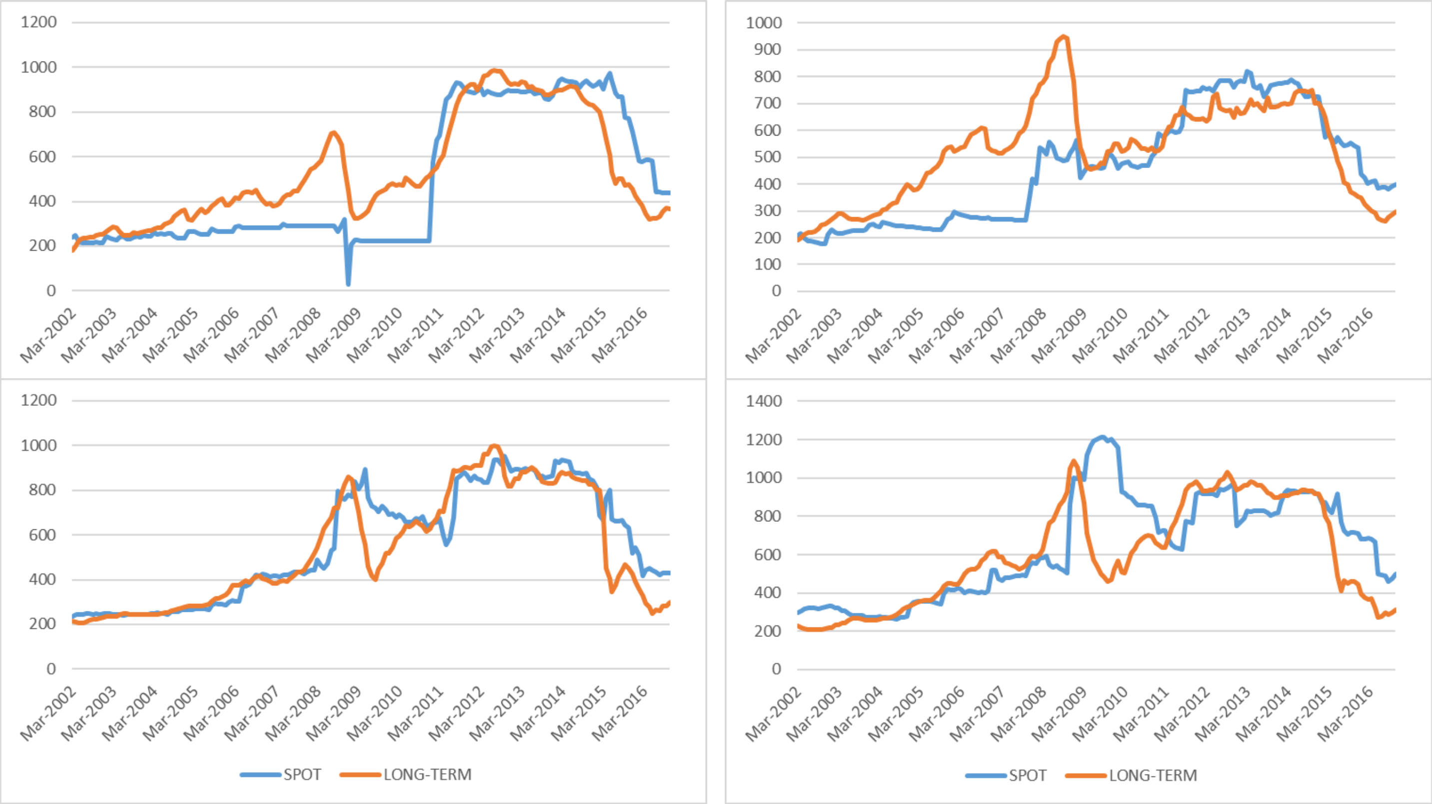
1. Generating and Handling Data

Japan LNG Price (USD/ton)

Korea LNG Price (USD/ton)

Indonesia

Qatar



1. Generating and Handling Data

Other Variables

- **Crude oil price: Japanese crude cocktail considering the correlation with each long-term contract price**
  - It is a proxy for the Indonesian Crude Price(ICP) which is the crude oil price index for Indonesian LNG contracts
- **Income: Industrial Production Index as a proxy of income**
  - It is a proxy for monthly income (Yu and Jin, 1992; Friedman and Kuttner, 1993)

Table 1. Correlation coefficients between LNG import prices and JCC

To	Japan		Korea	
From	Indonesia	Qatar	Indonesia	Qatar
JCC_{t-1}	0.911	0.903	0.905	0.890
JCC_{t-3}	0.916	0.958*	0.905	0.957*
$\sum_{i=1}^{3} JCC_{t-i}/3$	0.923*	0.940	0.915*	0.932

* denotes the largest correlation coefficient

2. Hypothesis Test

Hypothesis Test

- **Vuong's Closeness Test(1989)**
  - A pairwise test for nonnested models
  - Allowing us to determine which of the underlying behaviors most adequately explain the data (Gasmi et al., 1992)

<Equations>

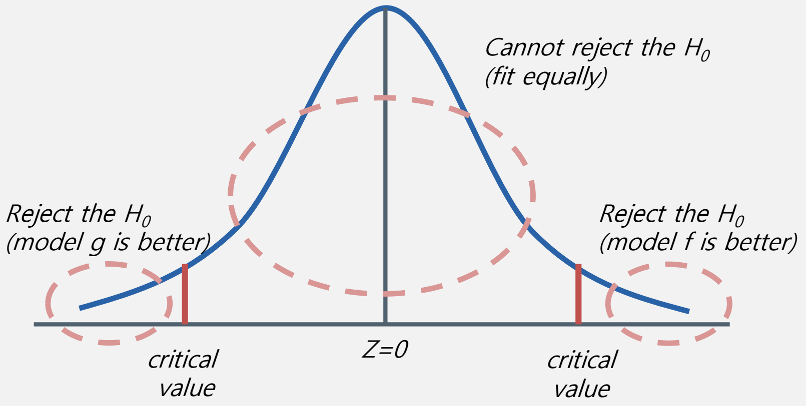
H_0: Two competing models fit equally well the data / H_a: One model fits better

Test Statistics for ***the FIRST model f and the SECOND model g,***

$$Z = \frac{L_f - L_g - \frac{K_f - K_g}{2} \log N}{\frac{1}{2}\left[\sum_{t=1}^{N}\left(\widehat{u_{f,t}}' \widehat{\Sigma_f}^{-1} \widehat{u_{f,t}} - \widehat{u_{g,t}}' \widehat{\Sigma_g}^{-1} \widehat{u_{g,t}}\right)^2\right]^{1/2}}$$

Where

1) L_f and L_g : Log-likelihood
2) K_f and K_g : The number of the estimated parameters
3) $\widehat{u_{f,t}}$ and $\widehat{u_{g,t}}$: The estimated residuals
4) $\widehat{\Sigma_f}^{-1}$ and $\widehat{\Sigma_g}^{-1}$: The estimated covariance matrices



1. The Case of Japan: Before Fukushima Nuclear Disaster

4 Spot Trading Cases – Long-term: Price Competition

- **Price collusion in spot trade is the best model**
  - The price collusion model fits better than any other models
  - Price Collusion > Price Leadership(Indonesia) ≒ Price Leadership(Qatar) > Price Competition

Table 2-1. The Result of Vuong's test – The Case of Japan; Before Fukushima Nuclear Disaster

	Price Leadership (Indonesia)	Price Leadership (Qatar)	Price Collusion best
Price Competition	-12.760***	-10.058***	-31.573***
Price Leadership (Indonesia)	-	0.406	-23.133***
Price Leadership (Qatar)	-	-	-28.533***

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

1. The Case of Japan: Before Fukushima Nuclear Disaster

4 Spot Trading Cases – Long-term: Price Leadership (Indonesia)

- **Price collusion in spot trade is the best model**
  - The price collusion model fits better than any other models
  - Price Collusion > Price Competition > Price Leadership(Qatar) > Price Leadership(Indonesia)

Table 2-2. The Result of Vuong's test – The Case of Japan; Before Fukushima Nuclear Disaster

	Price Leadership (Indonesia)	Price Leadership (Qatar)	Price Collusion best
Price Competition	16.392***	6.548***	-5.754***
Price Leadership (Indonesia)	-	-6.659***	-10.835***
Price Leadership (Qatar)	-	-	-8.289***

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

1. The Case of Japan: Before Fukushima Nuclear Disaster

4 Spot Trading Cases – Long-term: Price Leadership (Qatar)

- **Price leadership of Indonesia in spot trade is the best model**
  - The price leadership model of Indonesia fits better than any other models
  - Price Leadership(Indonesia) > Price Collusion > Price Competition > Price Leadership(Qatar)

Table 2-3. The Result of Vuong's test – The Case of Japan; Before Fukushima Nuclear Disaster

	Price Leadership (Indonesia) best	Price Leadership (Qatar)	Price Collusion
Price Competition	-7.692***	9.880***	-1.695*
Price Leadership (Indonesia) best	-	11.968***	3.349***
Price Leadership (Qatar)	-	-	-8.502***

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

1. The Case of Japan: Before Fukushima Nuclear Disaster

4 Spot Trading Cases – Long-term: Price Collusion

- **Price leadership of Qatar in spot trade is the best model**
  - The price leadership model of Qatar fits better than any other models
  - Price Leadership(Qatar) > Price Leadership(Indonesia) ≒ Price Collusion > Price Competition

Table 2-4. The Result of Vuong's test – The Case of Japan; Before Fukushima Nuclear Disaster

	Price Leadership (Indonesia)	Price Leadership (Qatar) best	Price Collusion
Price Competition	-20.322***	-41.885***	-9.098***
Price Leadership (Indonesia)	-	-15.724***	0.725
Price Leadership (Qatar) best	-	-	11.646***

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

1. The Case of Japan: Before Fukushima Nuclear Disaster

Comparison of 4 selected Trading Cases

- **Spot: price collusion / Long-term: price leadership of Indonesia is the best model**
  - S: Price Collusion / L: Price Leadership (Indonesia) > S: Price Collusion / L: Price Competition ≒ S: Price Leadership (Indonesia) / L: Price Leadership (Qatar) > S: Price Leadership (Qatar) / L: Price Collusion

Table 2-5. The Result of Vuong's test – The Case of Japan; Before Fukushima Nuclear Disaster

	S: Price Collusion L: Price Leadership (Indonesia) best	S: Price Leadership (Indonesia) L: Price Leadership (Qatar)	S: Price Leadership (Qatar) L: Price Collusion
S: Price Collusion L: Price Competition	-6.321***	0.092	2.330**
S: Price Collusion L: Price Leadership (Indonesia) best	-	5.191***	7.773***
S: Price Leadership (Indonesia) L: Price Leadership (Qatar)	-	-	2.987***

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

2. The Case of Japan: After Fukushima Nuclear Disaster

4 Spot Trading Cases – Long-term: Price Competition

- **Price competition in spot trade is the best model**
  - The price competition model fits better than any other models
  - Price Competition > Price Leadership(Qatar) > Price Leadership(Indonesia) ≒ Price Collusion

Table 3-1. The Result of Vuong's test – The Case of Japan; After Fukushima Nuclear Disaster

	Price Leadership (Indonesia)	Price Leadership (Qatar)	Price Collusion
Price Competition best	6.183***	2.190**	4.291***
Price Leadership (Indonesia)	-	-4.822***	0.404
Price Leadership (Qatar)	-	-	3.482***

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

2. The Case of Japan: After Fukushima Nuclear Disaster

4 Spot Trading Cases – Long-term: Price Leadership (Indonesia)

- **Price competition / Price Leadership (Indonesia) in spot trade are the best models**
  - The price competition and price leadership(Indonesia) models fit better equally than the other two models
  - Price Competition ≒ Price Leadership(Indonesia) > Price Leadership(Qatar) ≒ Price Collusion

Table 3-2. The Result of Vuong's test – The Case of Japan; After Fukushima Nuclear Disaster

	Price Leadership (Indonesia) best	**Price Leadership (Qatar)**	**Price Collusion**
Price Competition best	1.165	7.184***	2.718***
Price Leadership (Indonesia) best	-	4.298***	1.811*
Price Leadership (Qatar)	-	-	-0.576

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

2. The Case of Japan: After Fukushima Nuclear Disaster

4 Spot Trading Cases – Long-term: Price Leadership (Qatar)

- **Price competition in spot trade is the best model**
  - The price competition model fits better than any other models
  - Price Competition > Price Leadership(Qatar) ≒ Price Leadership(Indonesia) ≒ Price Collusion

Table 3-3. The Result of Vuong's test – The Case of Japan; After Fukushima Nuclear Disaster

	Price Leadership (Indonesia)	Price Leadership (Qatar)	Price Collusion
Price Competition best	5.477***	6.119***	3.777***
Price Leadership (Indonesia)	-	0.205	-0.214
Price Leadership (Qatar)	-	-	-0.465

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

2. The Case of Japan: After Fukushima Nuclear Disaster

4 Spot Trading Cases – Long-term: Price Collusion

- **Price competition / Price Leadership (Qatar) in spot trade are the best models**
  - The price competition and price leadership(Qatar) models fit better equally than the other two models
  - Price Leadership(Qatar) ≒ Price Competition > Price Leadership(Indonesia) ≒ Price Collusion

Table 3-4. The Result of Vuong's test – The Case of Japan; After Fukushima Nuclear Disaster

	Price Leadership (Indonesia)	Price Leadership (Qatar) best	Price Collusion
Price Competition best	3.421***	-1.208	2.687***
Price Leadership (Indonesia)	-	-3.218***	0.793
Price Leadership (Qatar) best	-	-	3.164***

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

2. The Case of Japan: After Fukushima Nuclear Disaster

Comparison of 4 selected Trading Cases

- **Spot: price collusion / Long-term: price competition or leadership of Qatar is the best model**
  - S: Price Competition, L: Price Leadership (Qatar) ≒ S: Price Competition, L: Price Competition > S: Price Competition, L: Price Leadership (Indonesia) ≒ S: Price Leadership (Qatar), L: Price Collusion

Table 3-5. The Result of Vuong's test – The Case of Japan; After Fukushima Nuclear Disaster

	S: Price Competition L: Price Leadership (Indonesia)	**S: Price Competition best L: Price Leadership (Qatar)**	**S: Price Leadership (Qatar) L: Price Collusion**
S: Price Competition best L: Price Competition	4.571***	-0.146	4.720***
S: Price Competition L: Price Leadership (Indonesia)	-	-5.401***	0.383
S: Price Competition best L: Price Leadership (Qatar)	-	-	4.769***

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

3. The Case of Korea: Before Fukushima Nuclear Disaster

4 Spot Trading Cases – Long-term: Price Competition

- **Price Leadership of Indonesia in spot trade is the best model**
  - The price leadership model of Indonesia fits better than any other models
  - Price Leadership(Indonesia) > Price Collusion ≒ Price Leadership(Qatar) > Price Competition

Table 4-1. The Result of Vuong's test – The Case of Korea; Before Fukushima Nuclear Disaster

	Price Leadership (Indonesia) best	Price Leadership (Qatar)	Price Collusion
Price Competition	-11.709***	-6.920***	-7.149***
Price Leadership (Indonesia) best	-	9.000***	10.319***
Price Leadership (Qatar)	-	-	0.771

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

3. The Case of Korea: Before Fukushima Nuclear Disaster

4 Spot Trading Cases – Long-term: Price Leadership (Indonesia)

- **Price collusion in spot trade is the best model**
  - The price collusion model of Indonesia fits better than any other models
  - Price Collusion > Price Competition > Price Leadership(Qatar) > Price Leadership (Indonesia)

Table 4-2. The Result of Vuong's test – The Case of Korea; Before Fukushima Nuclear Disaster

	Price Leadership (Indonesia)	Price Leadership (Qatar)	Price Collusion (best)
Price Competition	10.184***	5.399***	-3.806***
Price Leadership (Indonesia)	-	-3.192***	-6.923***
Price Leadership (Qatar)	-	-	-5.950***

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

3. The Case of Korea: Before Fukushima Nuclear Disaster

4 Spot Trading Cases – Long-term: Price Leadership (Qatar)

- **Price Leadership of Qatar in spot trade is the best model**
  - The price leadership model of Qatar fits better than any other models
  - Price Leadership(Qatar) > Price Collusion ≒ Price Competition > Price Leadership(Indonesia)

Table 4-3. The Result of Vuong's test – The Case of Korea; Before Fukushima Nuclear Disaster

	Price Leadership (Indonesia)	Price Leadership (Qatar) best	Price Collusion
Price Competition	10.776***	-8.793***	-0.266
Price Leadership (Indonesia)	-	-13.417***	-6.923***
Price Leadership (Qatar) best	-	-	5.801***

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

3. The Case of Korea: Before Fukushima Nuclear Disaster

4 Spot Trading Cases – Long-term: Price Collusion

- **Price collusion in spot trade is the best model**
  - The price collusion model fits better than any other models
  - Price Collusion > Price Competition > Price Leadership(Qatar) > Price Leadership(Indonesia)

Table 4-4. The Result of Vuong's test – The Case of Korea; Before Fukushima Nuclear Disaster

	Price Leadership (Indonesia)	Price Leadership (Qatar)	best Price Collusion
Price Competition	10.184***	5.399***	-8.751***
Price Leadership (Indonesia)	-	-3.192***	-10.903***
Price Leadership (Qatar)	-	-	-11.016***

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

3. The Case of Korea: Before Fukushima Nuclear Disaster

Comparison of 4 selected Trading Cases

- **Spot/Long-term: Price Leadership of Qatar is the best model**
  - S: Price Leadership(Qatar) > S: Price Collusion > S: Price Collusion > S: Price Leadership(Indonesia)
    L: Price Leadership(Qatar) L: Price Collusion L: Price Leadership(Indonesia) L: Price Competition

Table 4-5. The Result of Vuong's test – The Case of Korea; Before Fukushima Nuclear Disaster

	S: Price Collusion L: Price Leadership (Indonesia)	S: Price Leadership (Qatar) best L: Price Leadership (Qatar)	L: Price Collusion L: Price Collusion
S: Price Leadership (Indonesia) L: Price Competition	-40.536***	-51.771***	-61.076***
S: Price Collusion L: Price Leadership (Indonesia)	-	-5.833***	-4.579***
S: Price Leadership (Qatar) best L: Price Leadership (Qatar)	-	-	1.845*

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

4. The Case of Korea: After Fukushima Nuclear Disaster

4 Spot Trading Cases – Long-term: Price Competition

- **Price competition in spot trade is the best model**
  - The price competition model fits better than any other models
  - Price Competition > Price Leadership(Indonesia) ≒ Price Collusion > Price Leadership(Indonesia)

Table 5-1. The Result of Vuong's test – The Case of Korea; After Fukushima Nuclear Disaster

	Price Leadership (Indonesia)	Price Leadership (Qatar)	Price Collusion
Price Competition best	2.568**	34.071***	3.222***
Price Leadership (Indonesia)	-	21.199***	1.509
Price Leadership (Qatar)	-	-	-17.500***

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

4. The Case of Korea: After Fukushima Nuclear Disaster

4 Spot Trading Cases – Long-term: Price Leadership (Indonesia)

- **Price competition / Price leadership (Qatar) in spot trade are the best models**
  - The price competition and leadership model of Qatar fit better equally than the other two models
  - Price Competition ≒ Price Leadership(Qatar) > Price Leadership (Indonesia) > Price Collusion

Table 5-2. The Result of Vuong's test – The Case of Korea; After Fukushima Nuclear Disaster

	Price Leadership (Indonesia)	Price Leadership (Qatar) best	Price Collusion
Price Competition best	6.101***	-1.496	8.189***
Price Leadership (Indonesia)	-	-5.272***	4.491***
Price Leadership (Qatar) best	-	-	8.379***

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

4. The Case of Korea: After Fukushima Nuclear Disaster

4 Spot Trading Cases – Long-term: Price Leadership (Qatar)

- **Price competition in spot trade is the best model**
  - The price competition model fits better than any other models
  - Price Competition > Price Leadership(Indonesia) > Price Collusion ≒ Price Leadership(Qatar)

Table 5-3. The Result of Vuong's test – The Case of Korea; After Fukushima Nuclear Disaster

	Price Leadership (Indonesia)	Price Leadership (Qatar)	Price Collusion
Price Competition best	2.597***	5.942***	4.061***
Price Leadership (Indonesia)	-	2.114**	1.816*
Price Leadership (Qatar)	-	-	-0.060

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

4. The Case of Korea: After Fukushima Nuclear Disaster

4 Spot Trading Cases – Long-term: Price Collusion

- **Price Leadership of Qatar in spot trade is the best model**
  - The price leadership model of Qatar fits better than any other models
  - Price Leadership(Qatar) > Price Collusion ≒ Price Competition > Price Leadership (Indonesia)

Table 5-4. The Result of Vuong's test – The Case of Korea; After Fukushima Nuclear Disaster

	Price Leadership (Indonesia)	Price Leadership (Qatar) best	Price Collusion
Price Competition	5.730***	-7.715***	-1.210
Price Leadership (Indonesia)	-	-9.432***	-3.194***
Price Leadership (Qatar) best	-	-	2.592***

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

4. The Case of Korea: After Fukushima Nuclear Disaster

Comparison of 4 selected Trading Cases

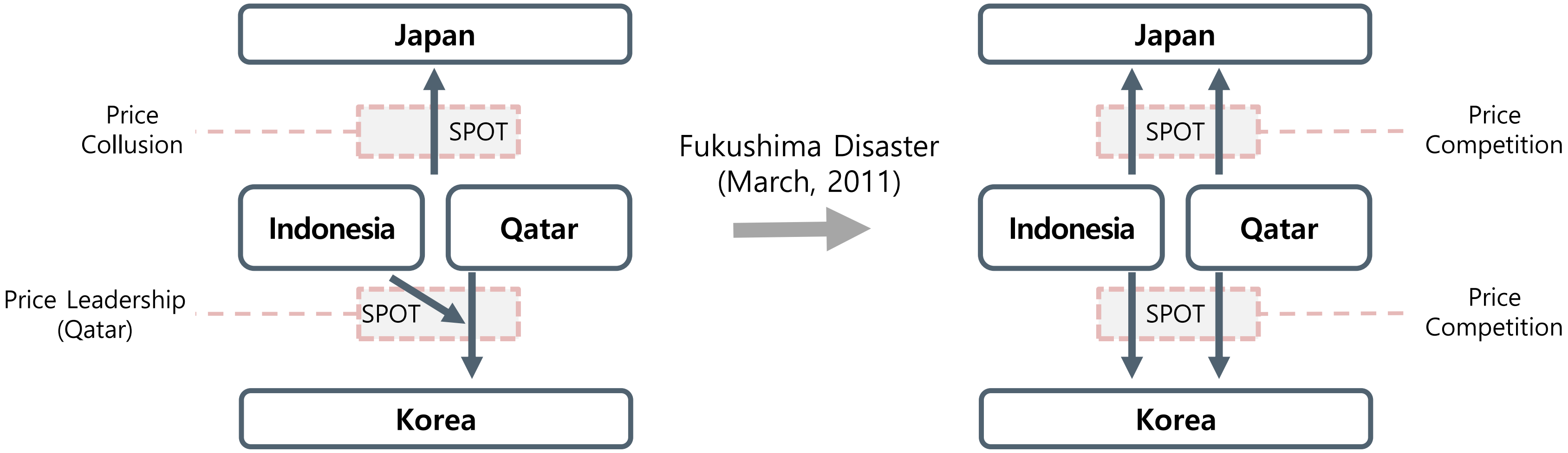
- **Spot: Price Competition / Long-term: Price Leadership of Qatar in spot trade is the best model**
  - S: Price Competition > S: Price Competition ≒ S: Price Leadership(Qatar) ≒ S: Price Leadership(Qatar)
    L: Price Leadership(Qatar) L: Price Competition L: Price Leadership(Indonesia) L: Price Collusion

Table 5-5. The Result of Vuong's test – The Case of Korea; After Fukushima Nuclear Disaster

	S: Price Leadership (Qatar) L: Price Leadership (Indonesia)	**S: Price Competition best L: Price Leadership (Qatar)**	**S: Price Leadership (Qatar) L: Price Collusion**
S: Price Competition L: Price Competition	-0.570	-2.698***	0.236
S: Price Leadership (Qatar) L: Price Leadership (Indonesia)	-	-2.544**	1.035
S: Price Competition best L: Price Leadership (Qatar)	-	-	3.802***

Null Hypothesis: Each model fits the data equally
*, **, and *** denotes that null hypothesis is rejected at 10%, 5%, 1% significance level, respectively.
Negative test statistics mean that the model in the column fits better.
Positive test statistics mean that the model in the row fits better.

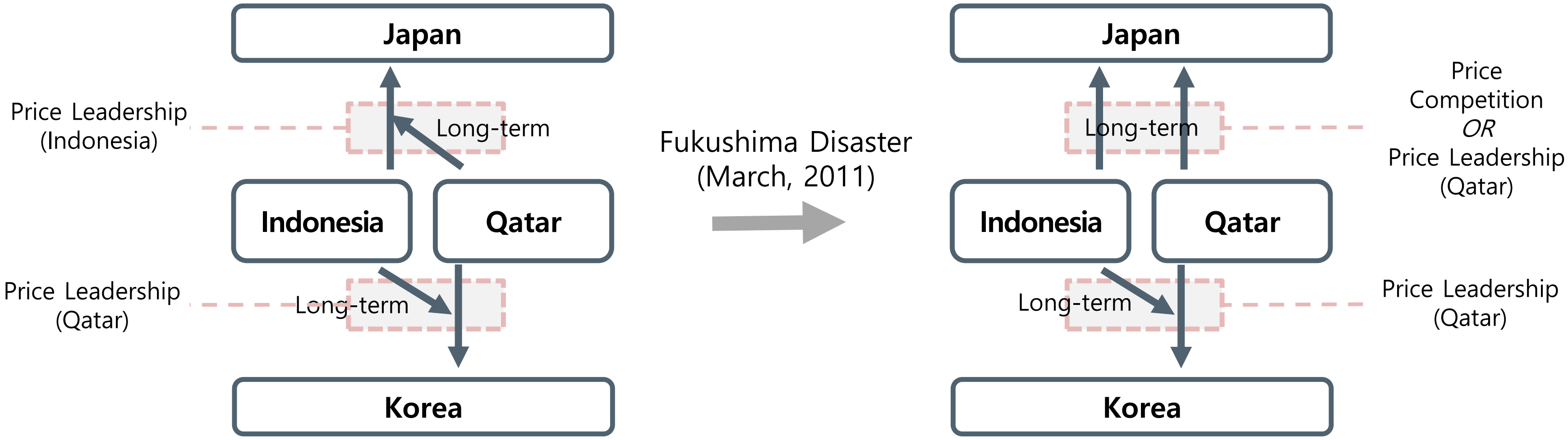
3. The Change of Trade Structure: Spot trade



Key Finding

- **The LNG spot trade became competitive**
  - It is difficult to hold collusion when the current demand is bigger than the expected demand of future(Rotemberg and Saloner, 1986; Haltiwanger and Harrington, 1991; Borenstein and Shepard, 1996)

3. The Change of Trade Structure: Long-term trade



Key Finding

- **The balance of power remained unchanged for Korea;**
- **Qatar acquired or Indonesia lost its market power**
  - The drop of the LNG exporting volume of Indonesia probably had an effect on losing its market power.

1. Conclusion and Future Study

Conclusion

- **Fukushima Nuclear Disaster could be a opportunity for Japan and Korea**
  - When it comes to importing ***the spot LNG***
  - The LNG spot trade became competitive
- **In the long-term tradings, Qatar acquired or Indonesia lost its market power**
  - It may be because of the drop of the LNG exporting volume of Indonesia.
  - It is hard to point out that it's because of Fukushima Nuclear Disaster.
- **When considering the expansion of the spot LNG imports, it is necessary to pay attention to the collusive behavior of exporting countries**
  - There is an incentive to do collusive behavior when the current demand is smaller than the expected demand of future(Rotemberg and Saloner, 1986; Haltiwanger and Harrington, 1991; Borenstein and Shepard, 1996)

Future Study

- **Considering *Russian Pipeline Natural Gas;* change the market structure?**

Thank you

11 June, 2018

Presenter: Gobong Choi (gchoi0322@snu.ac.kr)

Gobong Choi & Eunnyeong Heo
Seoul National University, Rep. of Korea
By the Brain Korea 21 PLUS Project (No. 21A20130012821)

Supplementary Slide 1: Estimation

Estimation

- **Full Information Maximum Likelihood(FIML) estimation**
  - The same method used in Gasmi et al.(1992) and Carter and MacLaren(1997)
- **Estimating two regimes**
  - To consider a change of trade structure after Fukushima Nuclear Disaster (March, 2011)
- **Imposing constraints**
  - on the weights (λ and μ_i) in the joint profit function to insure that the weights are between 0 and 1 (Gasmi et al., 1992)
  - on the *risk-aversion coefficients* (θ_i^{IMP} *and* θ_i^{EXP}) *in the expected utility and profit functions to insure that the coefficients are between 1 and 10*

    ** Most individuals have risk aversions between 1 and 10 (Andrew Ang, 2014)*

<Equations>

For the weights, λ and μ_i ,

$$\lambda = e^{w_1} / \left(1 + e^{w_1}\right) \quad \text{and} \quad \mu_i = e^{w_{2,i}} / \left(1 + e^{w_{2,i}}\right)$$

For the risk-aversion coefficients, θ_i^{IMP} *and* θ_i^{EXP}

$$\theta_i^{IMP} = \left(1 + 9\, e^{w_3} / \left(1 + e^{w_3}\right)\right) \quad \text{and} \quad \theta_i^{EXP} = \left(1 + 9\, e^{w_4} / \left(1 + e^{w_4}\right)\right)$$