A Strategy of LNG Exporting Countries for Trading in the Northeast Asian Region:
Price Competition, Leadership, or Collusion?

21 June, 2017

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By the Brain Korea 21 PLUS Project (No. 21A20130012821)
I. Introduction
II. Model Specification
III. Methodology
IV. Results
V. Conclusion and Future Study
1. 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 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)
2. Research Framework

Research Question
• How have major LNG exporters determined spot prices in Northeast Asia?
• Have they determined the LNG spot 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

Constructing Simultaneous Equation Models for Japan and Korea

Case 1. Price Competition
Case 2. Price Leadership - Indonesia
Case 3. Price Leadership - Qatar
Case 4. Price Collusion

Estimating Each Case for Two Periods

Vuong’s Closeness Test
1. Basic Assumptions and Settings

- **Case 1**: Price Competition (Duopolistic)
  - Importers: Japan OR Korea
  - Exporters: Indonesia AND Qatar

- **Case 2**: Price Leadership – Indonesia

- **Case 3**: Price Leadership – Qatar

- **Case 4**: Price Collusion

- **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
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

The general form of the simultaneous equations model

Constraints associated with a particular case are imposed on the parameter matrix and vector

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

- Demand Functions
- F.O.C.s of Spot pricing (4 cases)
- F.O.C.s of Re-negotiating (1 case)
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>**

\[ q_i^s = \alpha_i + \beta_{1,i}P_{IND}^s + \beta_{2,i}P_{QAT}^s + \gamma_{1,i}P_{IND}^f + \gamma_{2,i}P_{QAT}^f + \delta_{1,i}INC + \delta_{2,i}DUM_{summer} + \delta_{3,i}DUM_{winter} \]  
\[ \Pi_i = P_i^s q_i^s + P_i^f q_i^f - c_i(q_i^f + q_i^s) \]  
\[ EU_i = E\left[(P_i^s - P_i^f)q_i^f\right] - \frac{\theta_i^{MP}}{2} \text{var}\left[(P_i^s - P_i^f)q_i^f\right] \]  
\[ E\Pi_i = E(\Pi_i) - \frac{\theta_i^{EXP}}{2} \text{var}(\Pi_i) \]  

**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) \(\theta_i^{MP}\) and \(\theta_i^{EXP}\) are risk-aversion coefficients of importer and exporters, respectively

\(\forall i = Indonesia, Qatar\)
3. Spot Trade - Case 1: Price Competition (Duopolistic)

Maximization Problem

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

\[ \frac{\partial \Pi_{\text{IND}}}{\partial P_{\text{IND}}^s} = q_{\text{IND}}^s + P_{\text{IND}}^s \frac{\partial q_{\text{IND}}^s}{\partial P_{\text{IND}}^s} - c_{\text{IND}} \frac{\partial q_{\text{IND}}^s}{\partial P_{\text{IND}}^s} = 0 \iff q_{\text{IND}}^s + \beta_{1,\text{IND}} P_{\text{IND}}^s - c_{\text{IND}} \beta_{1,\text{IND}} = 0 \] \hspace{1cm} (5)

\[ \frac{\partial \Pi_{\text{QAT}}}{\partial P_{\text{QAT}}^s} = q_{\text{QAT}}^s + P_{\text{QAT}}^s \frac{\partial q_{\text{QAT}}^s}{\partial P_{\text{QAT}}^s} - c_{\text{QAT}} \frac{\partial q_{\text{QAT}}^s}{\partial P_{\text{QAT}}^s} = 0 \iff q_{\text{QAT}}^s + \beta_{2,\text{QAT}} P_{\text{QAT}}^s - c_{\text{QAT}} \beta_{2,\text{QAT}} = 0 \] \hspace{1cm} (6)

For Indonesia,

For Qatar,
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,

\[
\frac{\partial \Pi_{\text{IND}}}{\partial P_{\text{IND}}^s} = q_{\text{IND}}^s + P_{\text{IND}} \frac{\partial q_{\text{IND}}^s}{\partial P_{\text{IND}}^s} - c_{\text{IND}} \frac{\partial q_{\text{IND}}^s}{\partial P_{\text{IND}}^s} = 0 \quad \leftrightarrow \quad q_{\text{IND}}^s + (\beta_{1,\text{IND}} + \beta_{2,\text{IND}} \frac{\partial P_{\text{QAT}}^s}{\partial P_{\text{IND}}^s})P_{\text{IND}}^s - c_{\text{IND}}(\beta_{1,\text{IND}} + \beta_{2,\text{IND}} \frac{\partial P_{\text{QAT}}^s}{\partial P_{\text{IND}}^s}) = 0
\]

(7)

For Qatar,

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

(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,

\[
\frac{\partial \Pi_{\text{IND}}}{\partial P_{\text{IND}}^S} = q^S_{\text{IND}} + P_{\text{IND}}^S \frac{\partial q^S_{\text{IND}}}{\partial P_{\text{IND}}^S} - c_{\text{IND}} \frac{\partial q^S_{\text{IND}}}{\partial P_{\text{IND}}^S} = 0 \iff q^S_{\text{IND}} + \beta_{1,\text{IND}} P_{\text{IND}}^S - c_{\text{IND}} \beta_{1,\text{IND}} = 0 \text{ and } \frac{\partial P_{\text{IND}}^S}{\partial P_{\text{QAT}}^S} = -\frac{\beta_{2,\text{IND}}}{\beta_{1,\text{IND}}} \tag{9}
\]

For Qatar,

\[
\frac{\partial \Pi_{\text{QAT}}}{\partial P_{\text{QAT}}^S} = q^S_{\text{QAT}} + P_{\text{QAT}}^S \frac{\partial q^S_{\text{QAT}}}{\partial P_{\text{QAT}}^S} - c_{\text{QAT}} \frac{\partial q^S_{\text{QAT}}}{\partial P_{\text{QAT}}^S} = 0 \iff q^S_{\text{QAT}} + (\beta_{2,\text{QAT}} + \beta_{1,\text{QAT}} \frac{\partial P_{\text{IND}}^S}{\partial P_{\text{QAT}}^S}) P_{\text{QAT}}^S - c_{\text{QAT}} (\beta_{2,\text{QAT}} + \beta_{1,\text{QAT}} \frac{\partial P_{\text{IND}}^S}{\partial P_{\text{QAT}}^S}) = 0 \tag{10}
\]
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, \( \Pi^J \)

\[
\Pi^J \equiv \lambda \Pi_{IND} + (1 - \lambda) \Pi_{QAT}
\]

where \( \lambda \) is a weight for the profit of Indonesia, \( 0 < \lambda < 1 \)

For Indonesia

\[
\frac{\partial \Pi^J}{\partial P_{IND}^S} = \lambda \frac{\partial \Pi_{IND}}{\partial P_{IND}^S} + (1 - \lambda) \frac{\partial \Pi_{QAT}}{\partial P_{IND}^S} = \lambda (q_{IND}^S + \beta_{1,IND}P_{IND}^S - c_{IND}\beta_{1,IND}) + (1 - \lambda)(\beta_{1,QAT}P_{QAT}^S - c_{QAT}\beta_{1,QAT}) = 0 \tag{12}
\]

For Qatar

\[
\frac{\partial \Pi^J}{\partial P_{QAT}^S} = \lambda \frac{\partial \Pi_{IND}}{\partial P_{QAT}^S} + (1 - \lambda) \frac{\partial \Pi_{QAT}}{\partial P_{QAT}^S} = \lambda (\beta_{2,IND}P_{IND}^S - c_{IND}\beta_{2,IND}) + (1 - \lambda)(q_{QAT}^S + \beta_{2,QAT}P_{QAT}^S - c_{QAT}\beta_{2,QAT}) = 0 \tag{13}
\]
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 and intercept term of the long-term contract price formula

<Equations>

Define the joint profit,

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

(14)

where \( \mu_i \) 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

the price formula of Long-term contract,

\[ P_i^f = A_i P_i^c + B_i \]

(15)
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:

\[ P_{t,\text{customs}} = \frac{\text{spot volume}_t}{\text{total volume}_t} P_{t,\text{spot}} + \frac{\text{longterm volume}_t}{\text{total volume}_t} P_{t,\text{longterm}} + \varepsilon_t \]  

(25)

State Equation:

\[ P_{t,\text{spot}} = \rho_1 P_{t-1,\text{spot}} + v_{1,t} \]  

(26)

\[ P_{t,\text{longterm}} = \rho_2 P_{t-1,\text{longterm}} + v_{2,t} \]  

(27)
1. Generating and Handling Data

Japan LNG Volume (millions ton)

Korea LNG Volume (millions ton)

Indonesia

Qatar

Ⅰ. Introduction / Ⅱ. Model Specification / Ⅲ. Methodology / IV. Results / V. Conclusion and Future Study
1. Generating and Handling Data

Ⅰ. Introduction / Ⅱ. Model Specification / Ⅲ. Methodology / IV. Results / V. Conclusion and Future Study

### Japan LNG Price (USD/ton)

- **Indonesia**
- **Qatar**

### Korea LNG Price (USD/ton)
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

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Japan</th>
<th>Korea</th>
</tr>
</thead>
<tbody>
<tr>
<td>JCC_{t-1}</td>
<td>Indonesia</td>
<td>0.911</td>
<td>0.905</td>
</tr>
<tr>
<td></td>
<td>Qatar</td>
<td>0.903</td>
<td>0.890</td>
</tr>
<tr>
<td>JCC_{t-3}</td>
<td>Indonesia</td>
<td>0.916</td>
<td>0.905</td>
</tr>
<tr>
<td></td>
<td>Qatar</td>
<td>0.958*</td>
<td>0.957*</td>
</tr>
<tr>
<td>\sum_{i=1}^{3} JCC_{t-i}/3</td>
<td>Indonesia</td>
<td>0.923*</td>
<td>0.915*</td>
</tr>
<tr>
<td></td>
<td>Qatar</td>
<td>0.940</td>
<td>0.932</td>
</tr>
</tbody>
</table>

* 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>

\[ Z = \frac{L_f - L_g - \frac{K_f - K_g}{2} \log N}{\frac{1}{2} \left[ \sum_{t=1}^{N} \left( \hat{u}_{f,t} \hat{\Sigma}_{f}^{-1} \hat{u}_{f,t} - \hat{u}_{g,t} \hat{\Sigma}_{g}^{-1} \hat{u}_{g,t} \right)^2 \right]^{1/2}} \]

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

Where

1) \( L_f \) and \( L_g \): Log-likelihood
2) \( K_f \) and \( K_g \): The number of the estimated parameters
3) \( \hat{u}_{f,t} \) and \( \hat{u}_{g,t} \): The estimated residuals
4) \( \hat{\Sigma}_{f}^{-1} \) and \( \hat{\Sigma}_{g}^{-1} \): The estimated covariance matrices
1. The Case of Japan

Before Fukushima Nuclear Disaster (Jun. 2002 ~ Feb. 2011)

- **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>
<thead>
<tr>
<th></th>
<th>Price Leadership (Indonesia)</th>
<th>Price Leadership (Qatar)</th>
<th>Price Collusion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price Competition</strong></td>
<td>-12.760***</td>
<td>-10.058***</td>
<td>-31.573***</td>
</tr>
<tr>
<td><strong>Price Leadership (Indonesia)</strong></td>
<td>-</td>
<td>0.406</td>
<td>-23.133***</td>
</tr>
<tr>
<td><strong>Price Leadership (Qatar)</strong></td>
<td>-</td>
<td>-</td>
<td>-28.533***</td>
</tr>
</tbody>
</table>

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

After Fukushima Nuclear Disaster (Mar. 2011 ~ Nov. 2016)

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

<table>
<thead>
<tr>
<th></th>
<th>Price Leadership (Indonesia)</th>
<th>Price Leadership (Qatar)</th>
<th>Price Collusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price Competition</td>
<td>6.183***</td>
<td>2.190**</td>
<td>4.291***</td>
</tr>
<tr>
<td>Price Leadership (Indonesia)</td>
<td>-</td>
<td>-4.822***</td>
<td>0.404</td>
</tr>
<tr>
<td>Price Leadership (Qatar)</td>
<td>-</td>
<td>-</td>
<td>3.482***</td>
</tr>
</tbody>
</table>

Null Hypothesis: Each model fits the data equally

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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 Korea

Before Fukushima Nuclear Disaster (Jun. 2002 ~ Feb. 2011)

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

<table>
<thead>
<tr>
<th></th>
<th>Price Leadership (Indonesia)</th>
<th>Price Leadership (Qatar)</th>
<th>Price Collusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price Competition</td>
<td>-11.709***</td>
<td>-6.920***</td>
<td>-7.149***</td>
</tr>
<tr>
<td>Price Leadership</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Indonesia)</td>
<td>-</td>
<td>9.000***</td>
<td>10.319***</td>
</tr>
<tr>
<td>Price Leadership</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Qatar)</td>
<td>-</td>
<td>-</td>
<td>0.771</td>
</tr>
</tbody>
</table>

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.
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2. The Case of Korea

After Fukushima Nuclear Disaster (Mar. 2011 ~ Nov. 2016)

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

<table>
<thead>
<tr>
<th></th>
<th>Price Leadership (Indonesia)</th>
<th>Price Leadership (Qatar)</th>
<th>Price Collusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price Competition</td>
<td>2.568**</td>
<td>34.071***</td>
<td>3.222***</td>
</tr>
<tr>
<td>Price Leadership</td>
<td>-</td>
<td>21.199***</td>
<td>1.509</td>
</tr>
<tr>
<td>(Indonesia)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price Leadership</td>
<td>-</td>
<td>-</td>
<td>-17.500***</td>
</tr>
<tr>
<td>(Qatar)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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)
  - The drop of the LNG exporting volume of Indonesia also probably had an effect on losing its market power.

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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

- **When considering the expansion of 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)
  - The new energy policy which is stated by Jae-in Moon, the new president of Korea, is to expand gas power plants and renewable energy while reducing coal and nuclear power plants

**Future Study**

- Considering *tacit collusion* in the long-term contract pricing
- Considering other LNG exporting countries: Australia, Russia, Malaysia
Thank You

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### Table 6. The Estimation Results – the Case of Japan

<table>
<thead>
<tr>
<th>Equation</th>
<th>Variable</th>
<th>Indonesia</th>
<th>Qatar</th>
<th>Indonesia</th>
<th>Qatar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>T-statistics</td>
<td>Coefficient</td>
<td>T-statistics</td>
<td>Coefficient</td>
</tr>
<tr>
<td><strong>Demand</strong></td>
<td>Constant</td>
<td>-2.121</td>
<td>-2.120**</td>
<td>0.155</td>
<td>0.154</td>
</tr>
<tr>
<td></td>
<td>$\text{Price}_{\text{IND}}$, Spot</td>
<td>-13.086</td>
<td>-11.169***</td>
<td>0.297</td>
<td>1.511</td>
</tr>
<tr>
<td></td>
<td>$\text{Price}_{\text{QAT}}$, Spot</td>
<td>29.224</td>
<td>26.903***</td>
<td>-0.982</td>
<td>-2.209**</td>
</tr>
<tr>
<td></td>
<td>$\text{Price}_{\text{QAT}}$, Long-term</td>
<td>26.254</td>
<td>10.879***</td>
<td>-0.753</td>
<td>-2.448**</td>
</tr>
<tr>
<td></td>
<td>Income</td>
<td>2.936</td>
<td>2.844***</td>
<td>0.027</td>
<td>0.169</td>
</tr>
<tr>
<td></td>
<td>Dummy$_{\text{summer}}$</td>
<td>-1.178</td>
<td>-1.178</td>
<td>0.445</td>
<td>0.445</td>
</tr>
<tr>
<td></td>
<td>Dummy$_{\text{winter}}$</td>
<td>-1.300</td>
<td>-1.299</td>
<td>0.549</td>
<td>0.546</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Marginal Cost</td>
<td>12.738</td>
<td>11.053</td>
<td>8.143</td>
<td>7.769</td>
</tr>
<tr>
<td><strong>Risk-aversion</strong></td>
<td><strong>Risk-aversion$_{\text{Japan}}$</strong></td>
<td>5.500</td>
<td>5.500</td>
<td>1.000</td>
<td>5.500</td>
</tr>
<tr>
<td></td>
<td><strong>Risk-aversion$_{\text{Exporter}}$</strong></td>
<td>0.566</td>
<td>0.501</td>
<td>0.003</td>
<td>0.503</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td><strong>Weight$_{\text{Exporter, Long-term}}$</strong></td>
<td>0.974</td>
<td>0.026</td>
<td>0.003</td>
<td>0.503</td>
</tr>
</tbody>
</table>
Supplementary Slide 2: Estimated Results of the Selected Models

Table 7. The Estimation Results – the Case of Korea

<table>
<thead>
<tr>
<th>Equation</th>
<th>Variable</th>
<th>Before Fukushima Nuclear Disaster</th>
<th></th>
<th></th>
<th>After Fukushima Nuclear Disaster</th>
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<tr>
<td></td>
<td></td>
<td>Indonesian</td>
<td>Qatar</td>
<td>Indonesian</td>
<td>Qatar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coefficient</td>
<td>T-statistics</td>
<td>Coefficient</td>
<td>T-statistics</td>
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<tr>
<td><strong>Demand</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>-1.711</td>
<td>-1.715*</td>
<td>-0.075</td>
<td>-0.075</td>
</tr>
<tr>
<td></td>
<td>Price\textsubscript{IND, Spot}</td>
<td>-0.206</td>
<td>-0.429</td>
<td>2.199</td>
<td>2.052**</td>
</tr>
<tr>
<td></td>
<td>Price\textsubscript{QAT, Spot}</td>
<td>0.067</td>
<td>0.662</td>
<td>-4.656</td>
<td>-4.673***</td>
</tr>
<tr>
<td></td>
<td>Price\textsubscript{IND, Long-term}</td>
<td>0.579</td>
<td>18.346***</td>
<td>11.122</td>
<td>18.919***</td>
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<tr>
<td></td>
<td>Price\textsubscript{QAT, Long-term}</td>
<td>-1.061</td>
<td>-26.153***</td>
<td>-19.969</td>
<td>-31.486***</td>
</tr>
<tr>
<td></td>
<td>Income</td>
<td>5.080</td>
<td>33.199***</td>
<td>94.133</td>
<td>93.197***</td>
</tr>
<tr>
<td></td>
<td>Dummy\textsubscript{summer}</td>
<td>0.286</td>
<td>0.290</td>
<td>10.331</td>
<td>10.332***</td>
</tr>
<tr>
<td></td>
<td>Dummy\textsubscript{winter}</td>
<td>0.466</td>
<td>0.605</td>
<td>10.346</td>
<td>10.352***</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Risk-aversion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Risk-aversion\textsubscript{Korea}</td>
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<td>5.500</td>
<td>5.505</td>
<td>5.526</td>
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<tr>
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<td>Risk-aversion\textsubscript{Exporter}</td>
<td>8.242</td>
<td>5.163</td>
<td>4.796</td>
<td>1.068</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weight\textsubscript{Exporter, Long-term}</td>
<td>0.496</td>
<td>0.500</td>
<td>0.495</td>
<td>0.487</td>
</tr>
</tbody>
</table>
Supplementary Slide 3: 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 ($\lambda$ and $\mu_i$) in the joint profit function to insure that the weights are between 0 and 1 (Gasmi et al., 1992)
  - on the risk-aversion coefficients ($\theta_i^{IMP}$ and $\theta_i^{EXP}$) 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, $\lambda$ and $\mu_i$,

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

For the risk-aversion coefficients, $\theta_i^{IMP}$ and $\theta_i^{EXP}$,

\[ \theta_i^{IMP} = \left(1 + 9 e^{w_3} \left/ \left(1 + e^{w_3}\right) \right. \right) \quad \text{and} \quad \theta_i^{EXP} = \left(1 + 9 e^{w_4} \left/ \left(1 + e^{w_4}\right) \right. \right) \]
For slope in the price formula,

\[
\frac{\partial E U_{i,T}}{\partial A_i} = -q_i f E_0(P_{i,T}^c) + \theta_i^{imp}(q_i f)^2 \left( cov_0(P_{i,T}^s, P_{i,T}^c) - A_i var_0(P_{i,T}^c) \right)
\]  

(16)

\[
\frac{\partial E \Pi_{i,T}}{\partial A_i} = \gamma_{k,i} E_0(P_{i,T}^s P_{i,T}^c) + (q_i f - \gamma_{k,i} c_i) E_0(P_{i,T}^c) - \theta_i^{exp}(A_{cov,i})
\]  

(17)

\[
A_{cov,i} = \gamma_{k,i} \left[ \alpha_i cov_0(P_{i,T}^s, P_{i,T}^s P_{i,T}^c) + \beta_{k,i} cov_0(P_{i,T}^s, P_{i,T}^c, P_{i,T}^c) + \beta_{-k,i} cov_0(P_{i,T}^s, P_{i,T}^s P_{i,T}^c, P_{i,T}^c) + A_i \gamma_{k,i} cov_0(P_{i,T}^s P_{i,T}^c, P_{i,T}^s P_{i,T}^c) + B_i \gamma_{k,i} cov_0(P_{i,T}^s P_{i,T}^c, P_{i,T}^c) + \gamma_{-k,i} cov_0(P_{i,T}^s P_{i,T}^c, P_{i,T}^s P_{i,T}^c) + \delta_{1,i} cov_0(INC_T, P_{i,T}^s P_{i,T}^c) + \delta_{2,i} cov_0(DUM_{sum}, P_{i,T}^s P_{i,T}^c) 
\right]
\]

- \gamma_{k,i} c_i \left[ \beta_{k,i} cov_0(P_{i,T}^s, P_{i,T}^s P_{i,T}^c) + \beta_{-k,i} cov_0(P_{i,T}^s, P_{i,T}^c, P_{i,T}^c) + A_i \gamma_{k,i} cov_0(P_{i,T}^c, P_{i,T}^c P_{i,T}^c) + \gamma_{-k,i} cov_0(P_{i,T}^c, P_{i,T}^c P_{i,T}^c) + \delta_{1,i} cov_0(INC_T, P_{i,T}^c) + \delta_{2,i} cov_0(DUM_{sum}, P_{i,T}^c) 
\right]

+ (q_i f - \gamma_{k,i} c_i) \left[ \alpha_i cov_0(P_{i,T}^s, P_{i,T}^c) + \beta_{k,i} cov_0(P_{i,T}^s, P_{i,T}^c) + \beta_{-k,i} cov_0(P_{i,T}^s, P_{i,T}^c, P_{i,T}^c) + A_i \gamma_{k,i} cov_0(P_{i,T}^c, P_{i,T}^c) + B_i \gamma_{k,i} cov_0(P_{i,T}^c, P_{i,T}^c) + \gamma_{-k,i} cov_0(P_{i,T}^c, P_{i,T}^c) + \delta_{1,i} cov_0(INC_T, P_{i,T}^c) + \delta_{2,i} cov_0(DUM_{sum}, P_{i,T}^c) 
\right]

+ \delta_{3,i} cov_0(DUM_{win}, P_{i,T}^c) \right] + (q_i f - \gamma_{k,i} c_i) q_i^{f} A_i cov_0(P_{i,T}^c, P_{i,T}^c) 

28
For intercept in the price formula, 

\[
\frac{\partial E_{U_i,T}}{\partial B_i} = -q_i^f \tag{18}
\]

\[
\frac{\partial E_{\Pi_{i,T}}}{\partial B_i} = \gamma_{k,i}E_0(p_{i,T}^s) + (q_i^f - \gamma_{k,i}c_i) - \theta_i^{exp}(B_{cov,i}) \tag{19}
\]

\[
B_{cov,i} = \gamma_{k,i}\left[\alpha_i\text{cov}_0(p_{i,T}^{p_{i,T},p_{i,T}^s}) + \beta_{k,i}\text{cov}_0(p_{i,T}^{p_{i,T}^s,p_{i,T}^s}) + \beta_{k,i}\text{cov}_0(p_{i,T}^{p_{i,T}^s,p_{i,T}^s},c_{i,T}^s) + A_i\gamma_{k,i}\text{cov}_0(p_{i,T}^{c_{i,T}^s,p_{i,T}^s}) + B_i\gamma_{k,i}\text{cov}_0(p_{i,T}^{p_{i,T}^s,p_{i,T}^s}) + \gamma_{k,i}\text{cov}_0(p_{i,T}^{p_{i,T}^s,p_{i,T}^s}) + \delta_{1,i}\text{cov}_0(INC_T,p_{i,T}^s) + \delta_{2,i}\text{cov}_0(DUM_{sum},p_{i,T}^s) + \delta_{3,i}\text{cov}_0(DUM_{win},p_{i,T}^s)\right] + q_i^f A_i\gamma_{k,i}\text{cov}_0(p_{i,T}^{p_{i,T}^s,p_{i,T}^s})
\]

\[
-\gamma_{k,i}c_i\left[\beta_{k,i}\text{cov}_0(p_{i,T}^{p_{i,T}^s,p_{i,T}^s}) + \beta_{k,i}\text{cov}_0(p_{i,T}^{p_{i,T}^s,p_{i,T}^s}) + A_i\gamma_{k,i}\text{cov}_0(p_{i,T}^{p_{i,T}^{p_{i,T}^s},p_{i,T}^s}) + \gamma_{k,i}\text{cov}_0(p_{i,T}^{p_{i,T}^s,p_{i,T}^s}) + \delta_{1,i}\text{cov}_0(INC_T,p_{i,T}^s)\right]
\]
Since it is assumed that the discount factors, $r^{imp}$ and $r^{exp}$, equal 1,

$$\frac{\partial \Pi^f_i}{\partial A_i} = (1 - \mu_i) \left[ \frac{\partial E U_{i,1}}{\partial A_i} + \frac{\partial E U_{i,2}}{\partial A_i} + \frac{\partial E U_{i,3}}{\partial A_i} \right] + \mu_i \left[ \frac{\partial E \Pi_{i,1}}{\partial A_i} + \frac{\partial E \Pi_{i,2}}{\partial A_i} + \frac{\partial E \Pi_{i,3}}{\partial A_i} \right] = 3(1 - \mu_i) \frac{\partial E U_i}{\partial A_i} + 3\mu_i \frac{\partial E \Pi_i}{\partial A_i} = \omega_1 A_i + \omega_2 B_i = 0 \quad (20)$$

$$\frac{\partial \Pi^f_i}{\partial B_i} = (1 - \mu_i) \left[ \frac{\partial E U_{i,1}}{\partial B_i} + \frac{\partial E U_{i,2}}{\partial B_i} + \frac{\partial E U_{i,3}}{\partial B_i} \right] + \mu_i \left[ \frac{\partial E \Pi_{i,1}}{\partial B_i} + \frac{\partial E \Pi_{i,2}}{\partial B_i} + \frac{\partial E \Pi_{i,3}}{\partial B_i} \right] = 3(1 - \mu_i) \frac{\partial E U_i}{\partial B_i} + 3\mu_i \frac{\partial E \Pi_i}{\partial B_i} = \omega_3 A_i + \omega_4 B_i = 0 \quad (21)$$

Assumption for the expectations and covariances for the future, based on the point of re-negotiation,

1) the expectations are equal to the means of variables now and during before two months ($T = t, t-1, t-2$)
2) the covariances are equal to the covariances of variables now and during before two months ($T = t, t-1, t-2$)

Then, for $i = Indonesia and Qatar$

$$A_i = f_A(q^f_i, c_i, parameters) \quad (22)$$

$$B_i = f_B(q^f_i, c_i, parameters) \quad (23)$$

$$P^f_i = f_A(\cdot)P^c_i + f_b(\cdot) \quad (24)$$