

# Investigating Price Determinant Factors in Long-Term Natural Gas Supply Contract

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# Introduction

## The possibility of the Northeast Asian PNG contract

- The Russian-Chinese pipeline construction was signed \$400 billion supply contract in 2015.
- Russia has been proceeded negotiations with Korea and Japan under consideration of North Korea as transit country.
- The Northeast Asian countries need to prepare the pricing formulas to suggest under changed condition .



(Source : Gazprom.com)

# Introduction

## Benchmark the European long-term gas contract

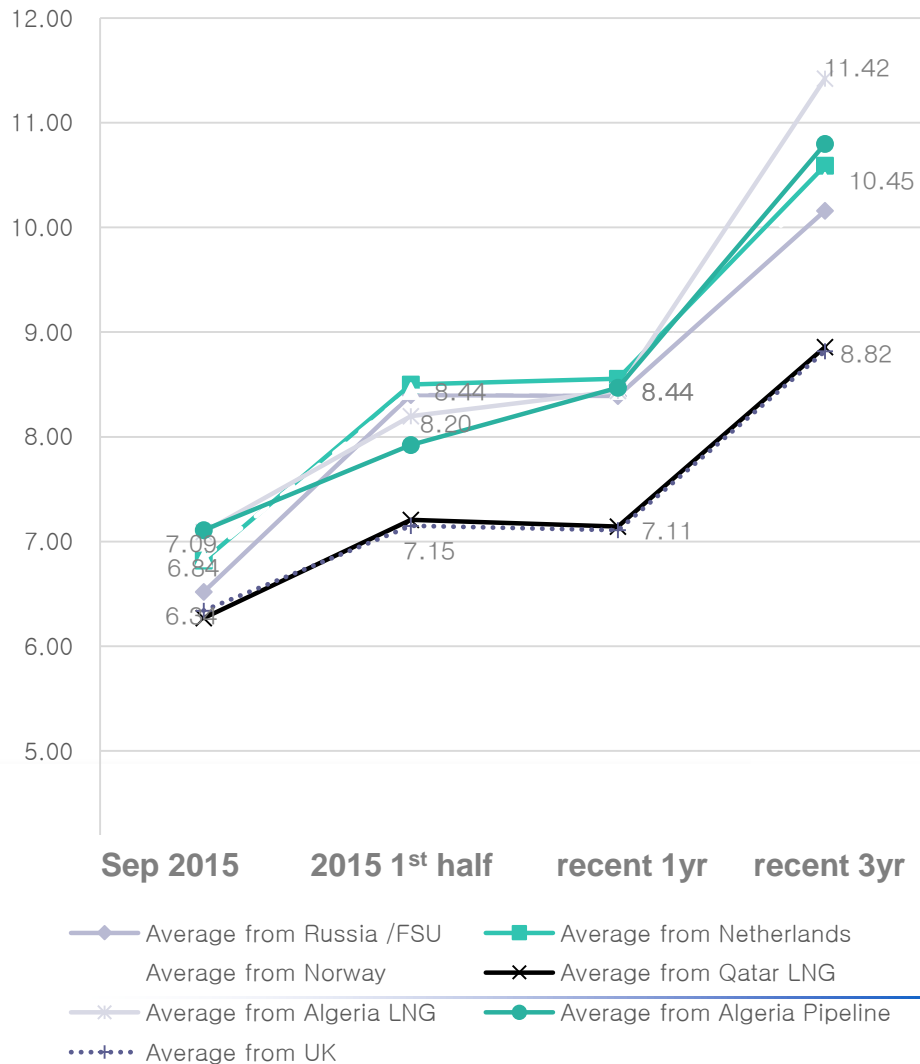
- Multiple supplier and buyers by type
- traditional bilateral long-term contract, specific infra installed, developed gas hub
- various contract condition on indexing



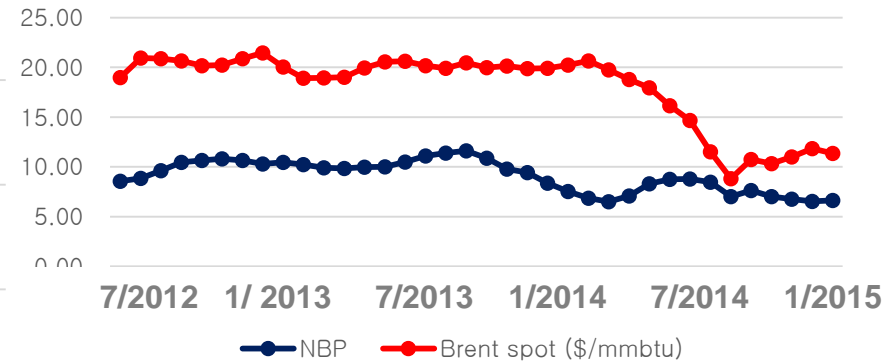
Source : eegas.com

# Overview of the European gas price indexation in contract price by supplier

## AVG. CONTRACT PRICE COMPARISON BY SUPPLIER



## Crude oil and spot gas price trend



- Indexation in the pricing formula in the contract is critical determinant factor in terms of contract price
- High level contract price : Algeria PNG/LNG, Netherlands
  - high oil indexed(Algeria)
  - 70-30% spot (Netherlands), “Netherlands Premium”
- Mid level contract price : Norway, Russia
  - 60-40% spot(Norway)
  - P0 10% discount, 15% spot(Russia-Germany)
  - 100% oil, P0 10% discount(Russia-France, Italy)
- Low level contract price : Qatar LNG, UK
  - 100% spot(Qatar-Belgium, France, UK)
  - Zeebrugge hub(UK-Belgium)
  - TTF(UK- Netherlands)

# Long-term supply contract

## Approach to pricing formula

**Substitution price** = contract price + cost (including transport cost)  
 ※ Price to secure competitiveness in market compared to substitutes

\*Market Value Principle  
**Net-back price**  
 =substitution value-cost

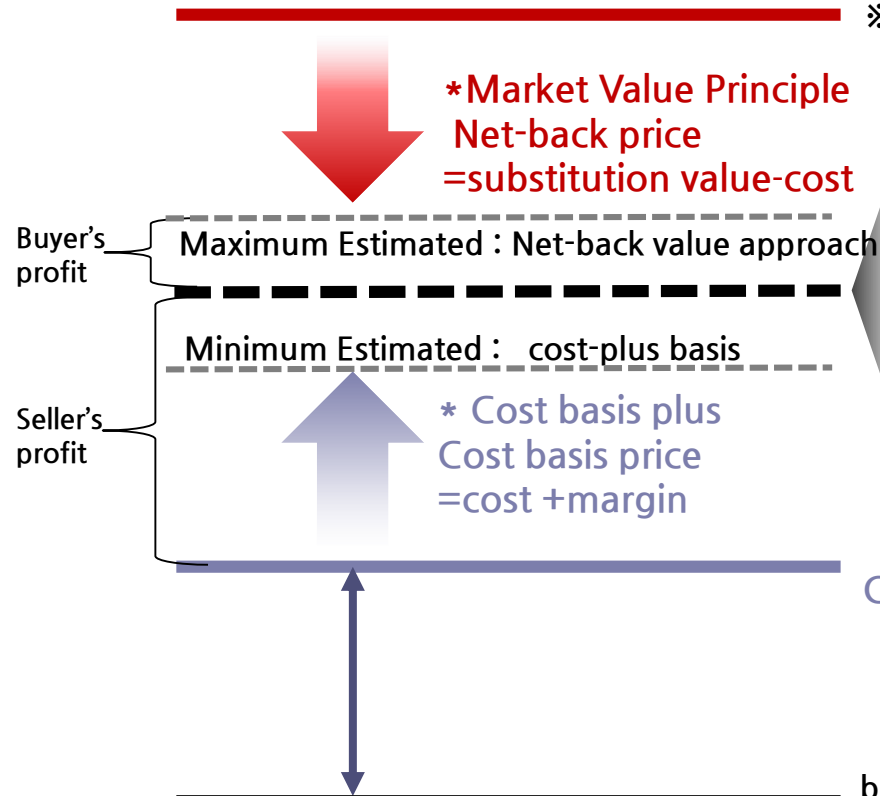
*Pricing Formula*

$$= P^{\circ} + [a \cdot PTF_{GO} \cdot CF_{GO} \cdot (GO - GO^{\circ}) + b \cdot PTF_{FO} \cdot CF_{FO} \cdot (FO - FO^{\circ})]$$

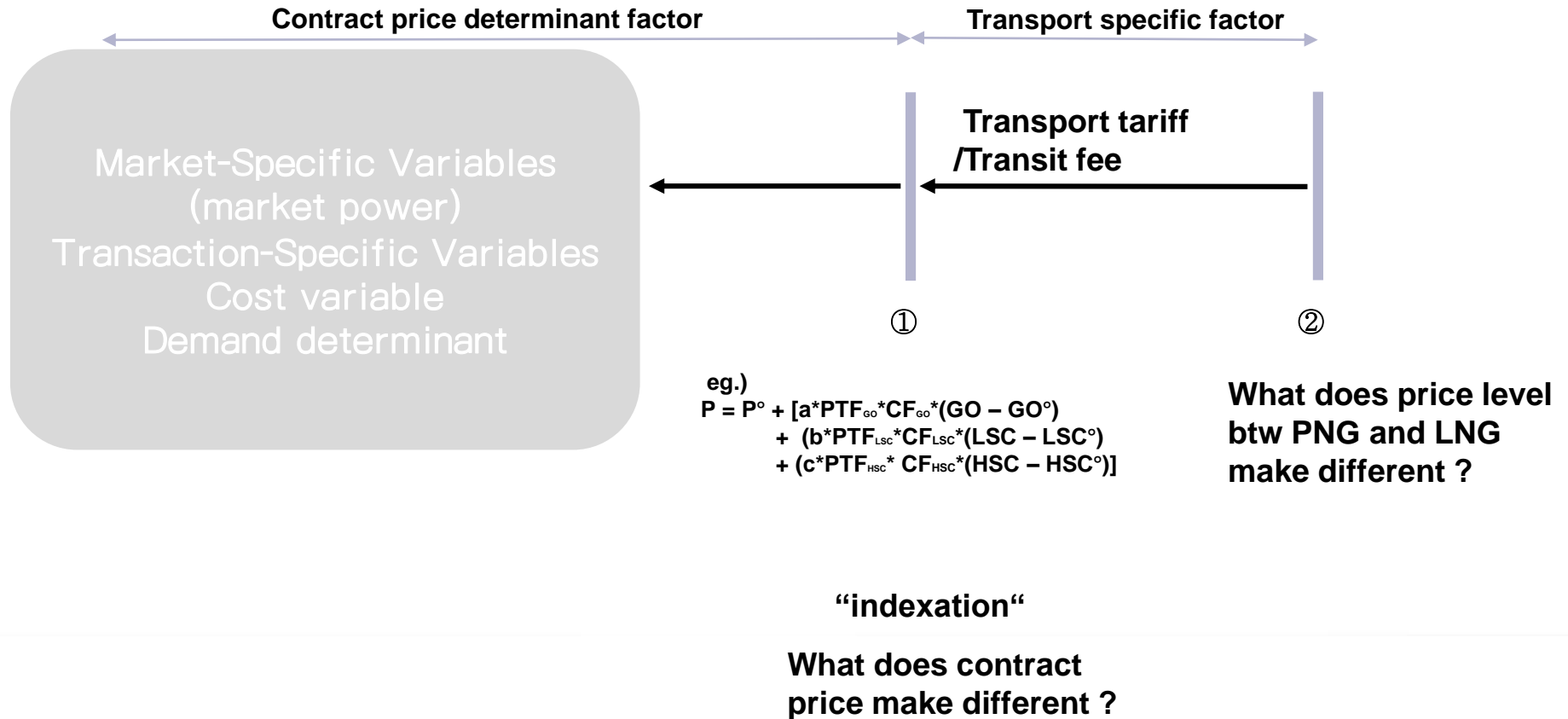
Profit determinant factors ;  
 Commercial risk on supply and risk sharing btw  
 supplier and buyer

**Cost** = Production cost(capital cost +O&M cost) + transport cost

baseline



# Investigating price determinant factors



**Table 7 Importing countries and sources**

| Importing country | PNG sources                 | LNG sources             |
|-------------------|-----------------------------|-------------------------|
| Belgium           | Netherlands, Norway         | Qatar, Algeria          |
| France            | Russia, Netherlands, Norway | Qatar, Algeria, Nigeria |
| Germany           | Russia, Netherlands, Norway | Qatar, Algeria          |
| Italy             | Russian, Norway, UK         | Qatar, Algeria          |
| Netherlands       | Norway, Algeria             | Qatar, Algeria, Nigeria |
| Spain             | Norway                      | Qatar                   |



Source : eegas.com

- combinations between supplier(7) and consumer countries(4) ; total of 28 (by type ; LNG. PNG)
- two annual periods of the year 2010 and 2014 according to renewing the long-term contract
- Price data was based on a survey of the trading prices for such entities of exporters and importers.

# Model

## Variables - Market-specific

|                                  | Variable name      |    | Descriptions  | Sources                             |
|----------------------------------|--------------------|----|---|-------------------------------------|
| <b>Market-specific Variables</b> | Seller pw to World | X1 | seller's power to world<br>seller's share of supply quantity to world consumption quantity                  | IEA(2015)                           |
|                                  | Seller pw to EU    | X2 | seller's power to Europe<br>seller's share of supply quantity to European region consumption<br>Quantity    | IEA(2015)                           |
|                                  | Buyer pw to World  | X3 | buyer's power to world<br>buyer's share of consumption quantity to world consumption quantity               | IEA(2015)                           |
|                                  | Buyer pw to EU     | X4 | buyer's power to Europe<br>buyer's share of consumption quantity to European region<br>consumption quantity | IEA(2015)                           |
|                                  | Supply ch          | X5 | Number of competing source  | IEA(2015)                           |
|                                  | Mkt strc           | X6 | market structure<br>market share of the largest company in gas industry                                     | OECD(2014)                          |
|                                  | Ownership          | X7 | public operator=1, predominantly owned by public shareholder(over 50%)                                      | Access website<br>by each cooperate |
|                                  | State own          | X8 | State has the ownership on that firm  | Access website<br>by each cooperate |

- relative position of the supplier or the consumer (NBER,1990; Knittel, 2003; Neuhoff &Hirschhausen, 2005)
- market structure and shareholder structure of consumer(Reymond, 2007)



# Model

## Variables - Transaction -specific

|                                | Variable name     |     | Descriptions  | Sources  |
|--------------------------------|-------------------|-----|---|--|
| Transaction-specific Variables | Seller share      | X9  | seller's share to demand country  | IEA(2015)  |
|                                | Buyer share       | X10 | buyer's share to supply country   | IEA(2015)  |
|                                | ACQ               | X11 | annual contract quantity  | WGI weekly, DIW Berlin(2014), Woodmac database           |
|                                | Period            | X12 | elapsed period of contract  | WGI weekly, DIW Berlin(2014), Woodmac database           |
|                                | Transit num       | X13 | number of transit country   |  |
|                                | Ukr dum           | X14 | pass through Ukraine or not   |  |
|                                | Flex              | X15 | flexibility of supply quantity<br>Mentioned the Take-or- Pay share or not | WGI weekly   |
|                                | Firm import share | X16 | Share of certain firm's contract quantity to total import quantity        | IEA(2015),WGI weekly, DIW Berlin(2014), Woodmac database |
|                                | PNG_LNG           | X17 | PNG=0, LNG=1  |  |

- Ratio of the quantity traded with particular counter part (NBER,1990), quantity agreed (Goldberg&Erickson, 1987)
- Flexibility of supplied quantity (Neuhoff &Hirschhausen, 2005; Asche et al., 2002)
- Transaction cost on renewing contract(Goldberg&Erickson, 1987)
- Transaction cost to transit other countries to supply (Reymond, 2007)

# Model

## Variables - cost, demand

|                         | Variable name    |     | Descriptions                          | Sources                           |
|-------------------------|------------------|-----|---------------------------------------|-----------------------------------|
| <b>Cost variables</b>   | Distance         | X18 | Transportation distance (km)          | LNG Insight                       |
|                         | LNG distance     | X19 | Transportation distance (km)          | LNG Insight                       |
|                         | PNG distance     | X20 | Transportation distance (km)          | Access website for each cooperate |
|                         | HL gas dum       | X21 | H-gas=1, L-gas=0                      | From Marcoogaz website            |
|                         | Proved reserve   | X22 | Estimated reserve by gas field        | IEA(2015), web searching          |
| <b>Demand Variables</b> | Total import     | X23 | Total import quantity                 | IEA(2015)                         |
|                         | Gas share        | X24 | Gas share to TPES                     | IEA(2015)                         |
|                         | Generation share | X25 | Generation share to final consumption | IEA(2015)                         |
|                         | Year dummy       | X26 | 2010=1, 2014=0                        |                                   |

- Transportation cost and price (Maxwell&Zhu, 2011) final price competitiveness (Quast & Locatelli, 1997)
- Heating value, proved reserve causing different cost (NBER,1990; Mu,2007; Neuhoff &Hirschhausen, 2005)
- Demand characteristics ; import dependency and supply structure (Knittel,2003; Reymond, 2007)

# Model

## High dimensional data analysis - LASSO

- $(x^i, y_i), i = 1, 2, \dots, N$
- $x^i = (x_{i1}, \dots, x_{ip})^T$  : predictor/potential variable(regressor)  
standardized with  $\sum_i x_{ij}/N = 0, \sum_i \frac{x_{ij}^2}{N} = 1$
- $y_i$  : the responses(contract price)
- $\hat{\beta} = (\hat{\beta}_1, \dots, \hat{\beta}_p)$
- the lasso estimate  $(\hat{\alpha}, \hat{\beta})$  is defined by

$$(\hat{\alpha}, \hat{\beta}) = \operatorname{argmin}\{\sum_{i=1}^p (y_i - \alpha - \sum_j \beta_j x_{ij})^2\} \text{ s.t. } \sum_j |\beta_j| \leq t \quad \text{Eq. (6)}$$

without loss of generality that  $\bar{y} = 0$  and hence omit  $\alpha$

$$(\hat{\beta}) = \operatorname{argmin}\{\sum_{i=1}^p (y_i - \sum_j \beta_j x_{ij})^2 + \lambda_t \sum_j |\beta_j|\} \quad \text{Eq. (7)}$$

K-fold cross-validation

- Indexing function :  $\kappa: \{1, \dots, N\} \mapsto \{1, \dots, K\}$
- Fitted function :  $\hat{f}^{-\kappa}(x)$
- the cross-validation estimate of prediction error

$$CV(\hat{f}) = \frac{1}{N} \sum_{i=1}^N L(y_i, \hat{f}^{-\kappa(i)}(x_i)) \quad \text{Eq. (8)}$$

## LASSO

- LASSO(Least Absolute Shrinkage and Selection Operator) ; prediction accuracy and drawing meaningful conclusion by shrinking some coefficient.
- overfitting through ordinary least square can be avoided by lasso with shrinking method (regularization, dimension reduction)
- Prediction error varies from tuning parameter  $\lambda$ , thus model selected results in the lowest prediction error with certain  $\lambda$  through lasso
- MATLAB code : LARS(Efron et al., 2004), GLMnet, cvglmnet(Friedman et al., 2010)

# Model

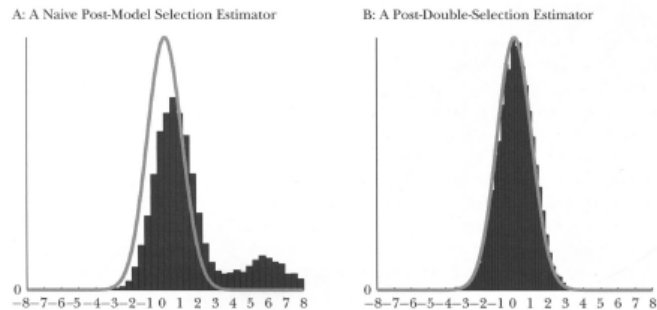
## High dimensional data analysis - Double selection

- $y_i$  : the responses(contract price)
- $d_i$  : treatment variable where  $E[\zeta_i|d_i, x_i, r_{yi}] = 0, r_{yi}$  is an approximation error

$$y_i = \alpha d_i + x_i' \theta_y + r_{yi} + \zeta_i$$

$$d_i = x_i' \theta_d + r_{di} + v_i, E[v_i | x_i, r_{di}] = 0 \quad \text{Eq. (9)}$$

Figure 1  
The "Double Selection" Approach to Estimation and Inference versus a Naive Approach: A Simulation from Belloni, Chernozhukov, and Hansen (forthcoming)  
(distributions of estimators from each approach)



Source: Belloni, Chernozhukov, and Hansen (forthcoming).  
Notes: The left panel shows the sampling distribution of the estimator of  $\alpha$  based on the first naive procedure described in this section: applying LASSO to the equation  $y_i = d_i + x_i' \theta_y + r_{yi} + \zeta_i$  while forcing the treatment variable to remain in the model by excluding  $\alpha$  from the LASSO penalty. The right panel shows the sampling distribution of the "double selection" estimator (see text for details) as in Belloni, Chernozhukov, and Hansen (forthcoming). The distributions are given for centered and studentized quantities.

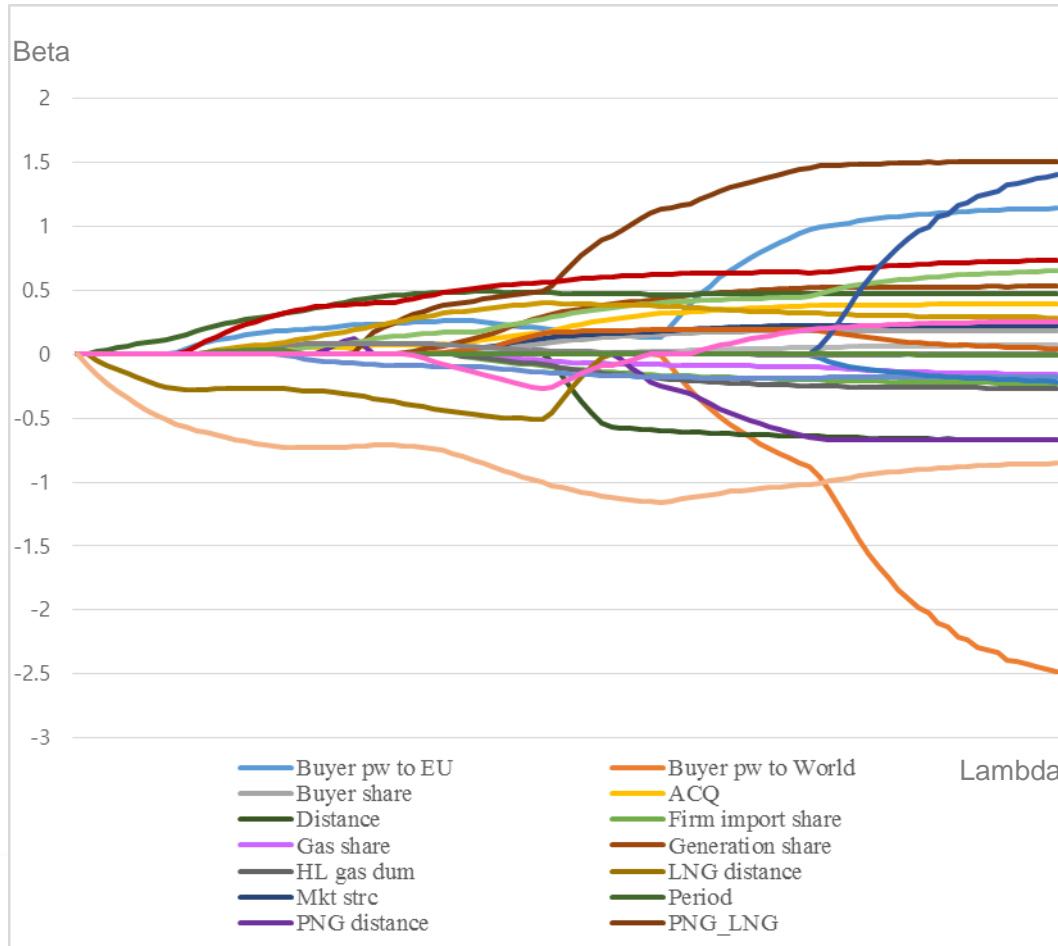
Source: Belloni(2014)

### Double selection to control

- After LASSO selection, estimating coefficient
- omitted variables bias ; Though prediction accuracy improve problem the nonzero coefficients tend to be substantially biased towards zero(Belloni et al., 2014)
- Not for fitting true model, but for estimating coefficient of particular variables
- Running 2<sup>nd</sup> Lasso to add control variable ( $x_i'$  on  $d_i$ ) and then regression to estimate
- Improve biasedness of  $\alpha$

# Results

## 1st lasso variable selection



$$y_i = 0.215BPE_i + 0.054ACQ_i - 0.299LD_i + 0.392PD_i + 0.383OWN_i - 0.060SS_i + 0.075SPE_i + 0.083SC_i + 0.163FLEX_i - 0.728YEAR_i$$

### 1st lasso

- performed on the 26 variables of European gas contract prices, the coefficient is displayed according to  $\lambda$
- the group of variables selected under the constraint condition of average value of  $\lambda$  (approximately 0.045)
- Buyer pw to EU (BPE), Annual Contract Quantity (ACQ), LNG Distance (LD), Period (PD), Ownership (OWN), Seller Share (SS), Seller pw to Europe (SPE), Supply Ch (SC), FLEX, Year Dum (YEAR)

# Results

## 2nd lasso variable selection

| Dependent variable with LASSO | Added variable to control  |
|-------------------------------|--|
| Buyer pw to EU                | Buyer share, Distance, Firm import share, Generation share, HL gas dum, UKR dum , Proved reserve, Stateown                         |
| ACQ                           | Generation share, HL gas dum, Mkt strc, Transit num, UKR dum, Proved reserve, State own, Seller pw to World, PNG LNG, Total import |
| LNG distance                  | Firm import share, Gas share, HL gas dum, Transit num, UKR dum , Proved reserve, Stateown, Seller pw to world, Buyer pw to world   |
| Period                        | Distance, Proved reserve, Buyer pw to World  |
| PNG distance                  | Buyer share, Firm import share, Gas share, HL gas dum, Mkt strc, Proved reserve, State own, Seller pw to world, Total import       |
| Ownership                     | Gas share, HL gas dum, Mkt strc  |
| Seller share                  | Buyer share, Firm import share, Gas share, HL gas dum, Transit num , Proved reserve, PNG_LNG, Seller pw to World, Total import     |
| Seller pw to EU               | Buyer share, Distance, Firm import share, Gass hare, Generation share, HL gas dum, Mkt strc, Transit num, UKR dum                  |
| Supplych                      | Firm import share, Generation share, Mkt strc, Transit num, UKR dum, State own, Seller pw to world                                 |
| Flex                          | firm_import_share, State own, PNG_LNG  |
| Year dum                      | Buyer share, Firm import share, Gas share, Generation share, Mkt strc, State own   |

# Results

## Regression results- linear specification

|              | Selected variables by LASSO / Linear Specification |                          |                          |                            |                           |                          |                             |                           |                          |                         |                              |
|--------------|--|--------------------------|--------------------------|----------------------------|---------------------------|--------------------------|-----------------------------|---------------------------|--------------------------|-------------------------|------------------------------|
|              | X2   | X4                       | X5                       | X7                         | X9                        | X11                      | X12                         | X15                       | X19                      | X20                     | X26                          |
|              | b/se   | b/se                     | b/se                     | b/se                       | b/se                      | b/se                     | b/se                        | b/se                      | b/se                     | b/se                    | b/se                         |
| sellerpwtoeu | <b>0.0654**</b><br>(0.029)                         | 0.0445<br>(0.033)        | 0.0828<br>(0.159)        | 0.0375**<br>(0.018)        | 0.1075<br>(0.164)         | 0.1063<br>(0.161)        | 0.0252<br>(0.020)           | 0.0300*<br>(0.016)        | 0.1171<br>(0.171)        | 0.1098<br>(0.173)       | 0.0386<br>(0.024)            |
| buyerpwtoeu  | -0.0056<br>(0.058)                                 | <b>0.0095</b><br>(0.064) | 0.0476<br>(0.056)        | 0.0497<br>(0.034)          | 0.1202<br>(0.362)         | 0.3281<br>(0.383)        | 0.2343<br>(0.373)           | 0.045<br>(0.050)          | 0.1982<br>(0.408)        | 0.1144<br>(0.396)       | 0.0478<br>(0.060)            |
| supplych     | 0.036<br>(0.062)                                   | 0.0356<br>(0.059)        | <b>0.0264</b><br>(0.064) | 0.0776<br>(0.050)          | 0.029<br>(0.063)          | 0.0023<br>(0.064)        | 0.074<br>(0.049)            | 0.037<br>(0.053)          | 0.051<br>(0.063)         | 0.0555<br>(0.062)       | 0.0196<br>(0.060)            |
| ownership    | 1.0347***<br>(0.372)                               | 1.0248***<br>(0.343)     | 0.8821**<br>(0.330)      | <b>0.8473**</b><br>(0.337) | 0.7405*<br>(0.385)        | 0.8038**<br>(0.387)      | 0.7355***<br>(0.247)        | 0.5927**<br>(0.248)       | 0.8748**<br>(0.379)      | 0.8064*<br>(0.405)      | 0.7946**<br>(0.334)          |
| seller_share | -0.0251<br>(0.016)                                 | -0.0184<br>(0.015)       | -0.0158<br>(0.011)       | -0.0159*<br>(0.009)        | <b>-0.0206</b><br>(0.017) | -0.0075<br>(0.012)       | -0.0142<br>(0.009)          | -0.0119<br>(0.009)        | -0.0185<br>(0.012)       | -0.0179<br>(0.016)      | -0.0149<br>(0.013)           |
| ACQ          | 0.1443<br>(0.087)                                  | 0.1575*<br>(0.087)       | 0.1094<br>(0.087)        | 0.0776*<br>(0.042)         | 0.1011<br>(0.080)         | <b>0.0404</b><br>(0.048) | 0.0572<br>(0.039)           | 0.0877<br>(0.070)         | 0.1342<br>(0.088)        | 0.1168<br>(0.085)       | 0.089<br>(0.075)             |
| period       | 0.0799**<br>(0.030)                                | 0.0865***<br>(0.030)     | 0.0888***<br>(0.029)     | 0.0862***<br>(0.028)       | 0.1110***<br>(0.031)      | 0.1018***<br>(0.031)     | <b>0.0976***</b><br>(0.028) | 0.1099***<br>(0.027)      | 0.1008***<br>(0.032)     | 0.0920***<br>(0.032)    | 0.0795***<br>(0.028)         |
| flex         | 0.1771<br>(0.397)                                  | 0.1214<br>(0.418)        | 0.4211<br>(0.372)        | 0.1621<br>(0.374)          | 0.4946<br>(0.467)         | 0.2564<br>(0.466)        | 0.2716<br>(0.326)           | <b>0.5980*</b><br>(0.342) | 0.0509<br>(0.469)        | 0.1097<br>(0.468)       | 0.4337<br>(0.343)            |
| LNG_distance | 0.0006<br>(0.001)                                  | 0.0008*<br>0.000         | -0.0001**<br>0.000       | -0.0001**<br>0.000         | -0.0002***<br>0.000       | -0.0002**<br>0.000       | 0.0003<br>0.000             | -0.0002***<br>0.000       | <b>-0.0002*</b><br>0.000 | -0.0001<br>0.000        | -0.0001*<br>0.000            |
| PNG_distance |  |                          | -0.0005<br>(0.001)       | -0.0005<br>0.000           | -0.0003<br>0.000          | -0.0004<br>(0.001)       |                             | -0.0002<br>0.000          | -0.0007<br>(0.001)       | <b>-0.0005</b><br>0.000 | -0.0004<br>0.000             |
| year_dum     | -1.7291***<br>(0.474)                              | -1.4403***<br>(0.355)    | -1.4358**<br>(0.616)     | -1.0876***<br>(0.270)      | -0.7138<br>(0.606)        | -1.1636*<br>(0.651)      | -0.8282<br>(0.569)          | -0.9372***<br>(0.255)     | -0.698<br>(0.703)        | -0.8317<br>(0.637)      | <b>-1.8487***</b><br>(0.488) |
| r2           | 0.73   | 0.72                     | 0.72                     | 0.7                        | 0.74                      | 0.75                     | 0.7                         | 0.73                      | 0.71                     | 0.71                    | 0.72                         |

\* p<0.1, \*\*p<0.05, \*\*\* p<0.01

- Seller's power to Europe(ratio of a supplier country's market share in European region market)
- **1%P increase, contract price tended to increase by 0.065\$/mmbtu, bargaining power of supplier**
- Europe seeking other sources of supply in an effort to reduce dependency on Russian gas

# Results

## Regression results- linear specification

|              | Selected variables by LASSO / Linear Specification |                          |                          |                            |                           |                          |                             |                           |                          |                         |                              |
|--------------|--|--------------------------|--------------------------|----------------------------|---------------------------|--------------------------|-----------------------------|---------------------------|--------------------------|-------------------------|------------------------------|
|              | X2   | X4                       | X5                       | X7                         | X9                        | X11                      | X12                         | X15                       | X19                      | X20                     | X26                          |
|              | b/se   | b/se                     | b/se                     | b/se                       | b/se                      | b/se                     | b/se                        | b/se                      | b/se                     | b/se                    | b/se                         |
| sellerpwtoeu | <b>0.0654**</b><br>(0.029)                         | 0.0445<br>(0.033)        | 0.0828<br>(0.159)        | 0.0375**<br>(0.018)        | 0.1075<br>(0.164)         | 0.1063<br>(0.161)        | 0.0252<br>(0.020)           | 0.0300*<br>(0.016)        | 0.1171<br>(0.171)        | 0.1098<br>(0.173)       | 0.0386<br>(0.024)            |
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| supplych     | 0.036<br>(0.062)                                   | 0.0356<br>(0.059)        | <b>0.0264</b><br>(0.064) | 0.0776<br>(0.050)          | 0.029<br>(0.063)          | 0.0023<br>(0.064)        | 0.074<br>(0.049)            | 0.037<br>(0.053)          | 0.051<br>(0.063)         | 0.0555<br>(0.062)       | 0.0196<br>(0.060)            |
| ownership    | 1.0347***<br>(0.372)                               | 1.0248***<br>(0.343)     | 0.8821**<br>(0.330)      | <b>0.8473**</b><br>(0.337) | 0.7405*<br>(0.385)        | 0.8038**<br>(0.387)      | 0.7355***<br>(0.247)        | 0.5927**<br>(0.248)       | 0.8748**<br>(0.379)      | 0.8064*<br>(0.405)      | 0.7946**<br>(0.334)          |
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| ACQ          | 0.1443<br>(0.087)                                  | 0.1575*<br>(0.087)       | 0.1094<br>(0.087)        | 0.0776*<br>(0.042)         | 0.1011<br>(0.080)         | <b>0.0404</b><br>(0.048) | 0.0572<br>(0.039)           | 0.0877<br>(0.070)         | 0.1342<br>(0.088)        | 0.1168<br>(0.085)       | 0.089<br>(0.075)             |
| period       | 0.0799**<br>(0.030)                                | 0.0865***<br>(0.030)     | 0.0888***<br>(0.029)     | 0.0862***<br>(0.028)       | 0.1110***<br>(0.031)      | 0.1018***<br>(0.031)     | <b>0.0976***</b><br>(0.028) | 0.1099***<br>(0.027)      | 0.1008***<br>(0.032)     | 0.0920***<br>(0.032)    | 0.0795***<br>(0.028)         |
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| LNG_distance | 0.0006<br>(0.001)                                  | 0.0008*<br>0.000         | -0.0001**<br>0.000       | -0.0001**<br>0.000         | -0.0002***<br>0.000       | -0.0002**<br>0.000       | 0.0003<br>0.000             | -0.0002***<br>0.000       | <b>-0.0002*</b><br>0.000 | -0.0001<br>0.000        | -0.0001*<br>0.000            |
| PNG_distance |  |                          | -0.0005<br>(0.001)       | -0.0005<br>0.000           | -0.0003<br>0.000          | -0.0004<br>(0.001)       |                             | -0.0002<br>0.000          | -0.0007<br>(0.001)       | <b>-0.0005</b><br>0.000 | -0.0004<br>0.000             |
| year_dum     | -1.7291***<br>(0.474)                              | -1.4403***<br>(0.355)    | -1.4358**<br>(0.616)     | -1.0876***<br>(0.270)      | -0.7138<br>(0.606)        | -1.1636*<br>(0.651)      | -0.8282<br>(0.569)          | -0.9372***<br>(0.255)     | -0.698<br>(0.703)        | -0.8317<br>(0.637)      | <b>-1.8487***</b><br>(0.488) |
| r2           | 0.73   | 0.72                     | 0.72                     | 0.7                        | 0.74                      | 0.75                     | 0.7                         | 0.73                      | 0.71                     | 0.71                    | 0.72                         |

\* p<0.1, \*\*p<0.05, \*\*\* p<0.01

- Ownership (The corporate structure of a consumer country, non-ownership = 1 )
- when there was ownership as opposed to none, the contract price increased by 0.85\$/mmbtu.
- for a consumer country's firm with ownership can have a comparative advantage in negotiating



# Results

## Regression results- linear specification

|              | Selected variables by LASSO / Linear Specification |                          |                          |                            |                           |                          |                             |                           |                          |                         |                              |
|--------------|--|--------------------------|--------------------------|----------------------------|---------------------------|--------------------------|-----------------------------|---------------------------|--------------------------|-------------------------|------------------------------|
|              | X2   | X4                       | X5                       | X7                         | X9                        | X11                      | X12                         | X15                       | X19                      | X20                     | X26                          |
|              | b/se   | b/se                     | b/se                     | b/se                       | b/se                      | b/se                     | b/se                        | b/se                      | b/se                     | b/se                    | b/se                         |
| sellerpwtoeu | <b>0.0654**</b><br>(0.029)                         | 0.0445<br>(0.033)        | 0.0828<br>(0.159)        | 0.0375**<br>(0.018)        | 0.1075<br>(0.164)         | 0.1063<br>(0.161)        | 0.0252<br>(0.020)           | 0.0300*<br>(0.016)        | 0.1171<br>(0.171)        | 0.1098<br>(0.173)       | 0.0386<br>(0.024)            |
| buyerpwtoeu  | -0.0056<br>(0.058)                                 | <b>0.0095</b><br>(0.064) | 0.0476<br>(0.056)        | 0.0497<br>(0.034)          | 0.1202<br>(0.362)         | 0.3281<br>(0.383)        | 0.2343<br>(0.373)           | 0.045<br>(0.050)          | 0.1982<br>(0.408)        | 0.1144<br>(0.396)       | 0.0478<br>(0.060)            |
| supplych     | 0.036<br>(0.062)                                   | 0.0356<br>(0.059)        | <b>0.0264</b><br>(0.064) | 0.0776<br>(0.050)          | 0.029<br>(0.063)          | 0.0023<br>(0.064)        | 0.074<br>(0.049)            | 0.037<br>(0.053)          | 0.051<br>(0.063)         | 0.0555<br>(0.062)       | 0.0196<br>(0.060)            |
| ownership    | 1.0347***<br>(0.372)                               | 1.0248***<br>(0.343)     | 0.8821**<br>(0.330)      | <b>0.8473**</b><br>(0.337) | 0.7405*<br>(0.385)        | 0.8038**<br>(0.387)      | 0.7355***<br>(0.247)        | 0.5927**<br>(0.248)       | 0.8748**<br>(0.379)      | 0.8064*<br>(0.405)      | 0.7946**<br>(0.334)          |
| seller_share | -0.0251<br>(0.016)                                 | -0.0184<br>(0.015)       | -0.0158<br>(0.011)       | -0.0159*<br>(0.009)        | <b>-0.0206</b><br>(0.017) | -0.0075<br>(0.012)       | -0.0142<br>(0.009)          | -0.0119<br>(0.009)        | -0.0185<br>(0.012)       | -0.0179<br>(0.016)      | -0.0149<br>(0.013)           |
| ACQ          | 0.1443<br>(0.087)                                  | 0.1575*<br>(0.087)       | 0.1094<br>(0.087)        | 0.0776*<br>(0.042)         | 0.1011<br>(0.080)         | <b>0.0404</b><br>(0.048) | 0.0572<br>(0.039)           | 0.0877<br>(0.070)         | 0.1342<br>(0.088)        | 0.1168<br>(0.085)       | 0.089<br>(0.075)             |
| period       | 0.0799**<br>(0.030)                                | 0.0865***<br>(0.030)     | 0.0888***<br>(0.029)     | 0.0862***<br>(0.028)       | 0.1110***<br>(0.031)      | 0.1018***<br>(0.031)     | <b>0.0976***</b><br>(0.028) | 0.1099***<br>(0.027)      | 0.1008***<br>(0.032)     | 0.0920***<br>(0.032)    | 0.0795***<br>(0.028)         |
| flex         | 0.1771<br>(0.397)                                  | 0.1214<br>(0.418)        | 0.4211<br>(0.372)        | 0.1621<br>(0.374)          | 0.4946<br>(0.467)         | 0.2564<br>(0.466)        | 0.2716<br>(0.326)           | <b>0.5980*</b><br>(0.342) | 0.0509<br>(0.469)        | 0.1097<br>(0.468)       | 0.4337<br>(0.343)            |
| LNG_distance | 0.0006<br>(0.001)                                  | 0.0008*<br>0.000         | -0.0001**<br>0.000       | -0.0001**<br>0.000         | -0.0002***<br>0.000       | -0.0002**<br>0.000       | 0.0003<br>0.000             | -0.0002***<br>0.000       | <b>-0.0002*</b><br>0.000 | -0.0001<br>0.000        | -0.0001*<br>0.000            |
| PNG_distance |  |                          | -0.0005<br>(0.001)       | -0.0005<br>0.000           | -0.0003<br>0.000          | -0.0004<br>(0.001)       |                             | -0.0002<br>0.000          | -0.0007<br>(0.001)       | <b>-0.0005</b><br>0.000 | -0.0004<br>0.000             |
| year_dum     | -1.7291***<br>(0.474)                              | -1.4403***<br>(0.355)    | -1.4358**<br>(0.616)     | -1.0876***<br>(0.270)      | -0.7138<br>(0.606)        | -1.1636*<br>(0.651)      | -0.8282<br>(0.569)          | -0.9372***<br>(0.255)     | -0.698<br>(0.703)        | -0.8317<br>(0.637)      | <b>-1.8487***</b><br>(0.488) |
| r2           | 0.73   | 0.72                     | 0.72                     | 0.7                        | 0.74                      | 0.75                     | 0.7                         | 0.73                      | 0.71                     | 0.71                    | 0.72                         |

\* p<0.1, \*\*p<0.05, \*\*\* p<0.01

- Period (passage of time since entering into contract)
- When such long-term contract passed 1 year, the contract price increased by 0.1\$/mmbtu
- decreasing incentives for price adjustments with the passage of time

# Results

## Regression results- linear specification

|              | Selected variables by LASSO / Linear Specification |                          |                          |                            |                           |                          |                             |                           |                          |                         |                              |
|--------------|--|--------------------------|--------------------------|----------------------------|---------------------------|--------------------------|-----------------------------|---------------------------|--------------------------|-------------------------|------------------------------|
|              | X2   | X4                       | X5                       | X7                         | X9                        | X11                      | X12                         | X15                       | X19                      | X20                     | X26                          |
|              | b/se   | b/se                     | b/se                     | b/se                       | b/se                      | b/se                     | b/se                        | b/se                      | b/se                     | b/se                    | b/se                         |
| sellerpwtoeu | <b>0.0654**</b><br>(0.029)                         | 0.0445<br>(0.033)        | 0.0828<br>(0.159)        | 0.0375**<br>(0.018)        | 0.1075<br>(0.164)         | 0.1063<br>(0.161)        | 0.0252<br>(0.020)           | 0.0300*<br>(0.016)        | 0.1171<br>(0.171)        | 0.1098<br>(0.173)       | 0.0386<br>(0.024)            |
| buyerpwtoeu  | -0.0056<br>(0.058)                                 | <b>0.0095</b><br>(0.064) | 0.0476<br>(0.056)        | 0.0497<br>(0.034)          | 0.1202<br>(0.362)         | 0.3281<br>(0.383)        | 0.2343<br>(0.373)           | 0.045<br>(0.050)          | 0.1982<br>(0.408)        | 0.1144<br>(0.396)       | 0.0478<br>(0.060)            |
| supplych     | 0.036<br>(0.062)                                   | 0.0356<br>(0.059)        | <b>0.0264</b><br>(0.064) | 0.0776<br>(0.050)          | 0.029<br>(0.063)          | 0.0023<br>(0.064)        | 0.074<br>(0.049)            | 0.037<br>(0.053)          | 0.051<br>(0.063)         | 0.0555<br>(0.062)       | 0.0196<br>(0.060)            |
| ownership    | 1.0347***<br>(0.372)                               | 1.0248***<br>(0.343)     | 0.8821**<br>(0.330)      | <b>0.8473**</b><br>(0.337) | 0.7405*<br>(0.385)        | 0.8038**<br>(0.387)      | 0.7355***<br>(0.247)        | 0.5927**<br>(0.248)       | 0.8748**<br>(0.379)      | 0.8064*<br>(0.405)      | 0.7946**<br>(0.334)          |
| seller_share | -0.0251<br>(0.016)                                 | -0.0184<br>(0.015)       | -0.0158<br>(0.011)       | -0.0159*<br>(0.009)        | <b>-0.0206</b><br>(0.017) | -0.0075<br>(0.012)       | -0.0142<br>(0.009)          | -0.0119<br>(0.009)        | -0.0185<br>(0.012)       | -0.0179<br>(0.016)      | -0.0149<br>(0.013)           |
| ACQ          | 0.1443<br>(0.087)                                  | 0.1575*<br>(0.087)       | 0.1094<br>(0.087)        | 0.0776*<br>(0.042)         | 0.1011<br>(0.080)         | <b>0.0404</b><br>(0.048) | 0.0572<br>(0.039)           | 0.0877<br>(0.070)         | 0.1342<br>(0.088)        | 0.1168<br>(0.085)       | 0.089<br>(0.075)             |
| period       | 0.0799**<br>(0.030)                                | 0.0865***<br>(0.030)     | 0.0888***<br>(0.029)     | 0.0862***<br>(0.028)       | 0.1110***<br>(0.031)      | 0.1018***<br>(0.031)     | <b>0.0976***</b><br>(0.028) | 0.1099***<br>(0.027)      | 0.1008***<br>(0.032)     | 0.0920***<br>(0.032)    | 0.0795***<br>(0.028)         |
| flex         | 0.1771<br>(0.397)                                  | 0.1214<br>(0.418)        | 0.4211<br>(0.372)        | 0.1621<br>(0.374)          | 0.4946<br>(0.467)         | 0.2564<br>(0.466)        | 0.2716<br>(0.326)           | <b>0.5980*</b><br>(0.342) | 0.0509<br>(0.469)        | 0.1097<br>(0.468)       | 0.4337<br>(0.343)            |
| LNG_distance | 0.0006<br>(0.001)                                  | 0.0008*<br>0.000         | -0.0001**<br>0.000       | -0.0001**<br>0.000         | -0.0002***<br>0.000       | -0.0002**<br>0.000       | 0.0003<br>0.000             | -0.0002***<br>0.000       | <b>-0.0002*</b><br>0.000 | -0.0001<br>0.000        | -0.0001*<br>0.000            |
| PNG_distance |  |                          | -0.0005<br>(0.001)       | -0.0005<br>0.000           | -0.0003<br>0.000          | -0.0004<br>(0.001)       |                             | -0.0002<br>0.000          | -0.0007<br>(0.001)       | <b>-0.0005</b><br>0.000 | -0.0004<br>0.000             |
| year_dum     | -1.7291***<br>(0.474)                              | -1.4403***<br>(0.355)    | -1.4358**<br>(0.616)     | -1.0876***<br>(0.270)      | -0.7138<br>(0.606)        | -1.1636*<br>(0.651)      | -0.8282<br>(0.569)          | -0.9372***<br>(0.255)     | -0.698<br>(0.703)        | -0.8317<br>(0.637)      | <b>-1.8487***</b><br>(0.488) |
| r2           | 0.73   | 0.72                     | 0.72                     | 0.7                        | 0.74                      | 0.75                     | 0.7                         | 0.73                      | 0.71                     | 0.71                    | 0.72                         |

\* p<0.1, \*\*p<0.05, \*\*\* p<0.01

- Flexibility(adjusting quantity supplied)
- when the agreement was set out to increase the flexibility of quantity, 0.6\$/mmbtu increase in contract price
- flexibility of quantity supplied undermines such stability, thereby incurring penalties

# Results

## Regression results- linear specification

|              | Selected variables by LASSO / Linear Specification |                          |                          |                            |                           |                          |                             |                           |                          |                         |                              |
|--------------|--|--------------------------|--------------------------|----------------------------|---------------------------|--------------------------|-----------------------------|---------------------------|--------------------------|-------------------------|------------------------------|
|              | X2   | X4                       | X5                       | X7                         | X9                        | X11                      | X12                         | X15                       | X19                      | X20                     | X26                          |
|              | b/se   | b/se                     | b/se                     | b/se                       | b/se                      | b/se                     | b/se                        | b/se                      | b/se                     | b/se                    | b/se                         |
| sellerpwtoeu | <b>0.0654**</b><br>(0.029)                         | 0.0445<br>(0.033)        | 0.0828<br>(0.159)        | 0.0375**<br>(0.018)        | 0.1075<br>(0.164)         | 0.1063<br>(0.161)        | 0.0252<br>(0.020)           | 0.0300*<br>(0.016)        | 0.1171<br>(0.171)        | 0.1098<br>(0.173)       | 0.0386<br>(0.024)            |
| buyerpwtoeu  | -0.0056<br>(0.058)                                 | <b>0.0095</b><br>(0.064) | 0.0476<br>(0.056)        | 0.0497<br>(0.034)          | 0.1202<br>(0.362)         | 0.3281<br>(0.383)        | 0.2343<br>(0.373)           | 0.045<br>(0.050)          | 0.1982<br>(0.408)        | 0.1144<br>(0.396)       | 0.0478<br>(0.060)            |
| supplych     | 0.036<br>(0.062)                                   | 0.0356<br>(0.059)        | <b>0.0264</b><br>(0.064) | 0.0776<br>(0.050)          | 0.029<br>(0.063)          | 0.0023<br>(0.064)        | 0.074<br>(0.049)            | 0.037<br>(0.053)          | 0.051<br>(0.063)         | 0.0555<br>(0.062)       | 0.0196<br>(0.060)            |
| ownership    | 1.0347***<br>(0.372)                               | 1.0248***<br>(0.343)     | 0.8821**<br>(0.330)      | <b>0.8473**</b><br>(0.337) | 0.7405*<br>(0.385)        | 0.8038**<br>(0.387)      | 0.7355***<br>(0.247)        | 0.5927**<br>(0.248)       | 0.8748**<br>(0.379)      | 0.8064*<br>(0.405)      | 0.7946**<br>(0.334)          |
| seller_share | -0.0251<br>(0.016)                                 | -0.0184<br>(0.015)       | -0.0158<br>(0.011)       | -0.0159*<br>(0.009)        | <b>-0.0206</b><br>(0.017) | -0.0075<br>(0.012)       | -0.0142<br>(0.009)          | -0.0119<br>(0.009)        | -0.0185<br>(0.012)       | -0.0179<br>(0.016)      | -0.0149<br>(0.013)           |
| ACQ          | 0.1443<br>(0.087)                                  | 0.1575*<br>(0.087)       | 0.1094<br>(0.087)        | 0.0776*<br>(0.042)         | 0.1011<br>(0.080)         | <b>0.0404</b><br>(0.048) | 0.0572<br>(0.039)           | 0.0877<br>(0.070)         | 0.1342<br>(0.088)        | 0.1168<br>(0.085)       | 0.089<br>(0.075)             |
| period       | 0.0799**<br>(0.030)                                | 0.0865***<br>(0.030)     | 0.0888***<br>(0.029)     | 0.0862***<br>(0.028)       | 0.1110***<br>(0.031)      | 0.1018***<br>(0.031)     | <b>0.0976***</b><br>(0.028) | 0.1099***<br>(0.027)      | 0.1008***<br>(0.032)     | 0.0920***<br>(0.032)    | 0.0795***<br>(0.028)         |
| flex         | 0.1771<br>(0.397)                                  | 0.1214<br>(0.418)        | 0.4211<br>(0.372)        | 0.1621<br>(0.374)          | 0.4946<br>(0.467)         | 0.2564<br>(0.466)        | 0.2716<br>(0.326)           | <b>0.5980*</b><br>(0.342) | 0.0509<br>(0.469)        | 0.1097<br>(0.468)       | 0.4337<br>(0.343)            |
| LNG_distance | 0.0006<br>(0.001)                                  | 0.0008*<br>0.000         | -0.0001**<br>0.000       | -0.0001**<br>0.000         | -0.0002***<br>0.000       | -0.0002**<br>0.000       | 0.0003<br>0.000             | -0.0002***<br>0.000       | <b>-0.0002*</b><br>0.000 | -0.0001<br>0.000        | -0.0001*<br>0.000            |
| PNG_distance |  |                          | -0.0005<br>(0.001)       | -0.0005<br>0.000           | -0.0003<br>0.000          | -0.0004<br>(0.001)       |                             | -0.0002<br>0.000          | -0.0007<br>(0.001)       | <b>-0.0005</b><br>0.000 | -0.0004<br>0.000             |
| year_dum     | -1.7291***<br>(0.474)                              | -1.4403***<br>(0.355)    | -1.4358**<br>(0.616)     | -1.0876***<br>(0.270)      | -0.7138<br>(0.606)        | -1.1636*<br>(0.651)      | -0.8282<br>(0.569)          | -0.9372***<br>(0.255)     | -0.698<br>(0.703)        | -0.8317<br>(0.637)      | <b>-1.8487***</b><br>(0.488) |
| r2           | 0.73   | 0.72                     | 0.72                     | 0.7                        | 0.74                      | 0.75                     | 0.7                         | 0.73                      | 0.71                     | 0.71                    | 0.72                         |

\* p<0.1, \*\*p<0.05, \*\*\* p<0.01

- LNG\_Distance
- transportation distance of LNG increased by 1km, the price decreased by 0.0002\$/mmbtu
- Contract price has a room for negotiating preservation of loss arising from transportation costs

# Results

## Regression results- log-linear specification

|                 | Selected variables by LASSO / Linear Specification |                          |                          |                           |                          |                          |                            |                          |                            |                            |                            |
|-----------------|--|--------------------------|--------------------------|---------------------------|--------------------------|--------------------------|----------------------------|--------------------------|----------------------------|----------------------------|----------------------------|
|                 | X2   | X4                       | X5                       | X7                        | X9                       | X11                      | X12                        | X15                      | X19                        | X20                        | X26                        |
|                 | b/se   | b/se                     | b/se                     | b/se                      | b/se                     | b/se                     | b/se                       | b/se                     | b/se                       | b/se                       | b/se                       |
| ln_sellerpwtoeu | <b>-0.0465</b><br>(0.139)                          | -0.038<br>(0.129)        | 0.0600**<br>(0.026)      | 0.0678**<br>(0.025)       |                          | 0.0288<br>(0.028)        | 0.0197<br>(0.025)          | 0.0600**<br>(0.024)      | 0.0233<br>(0.027)          |                            | -0.0338<br>(0.139)         |
| ln_buyerpwtoeu  | -0.1381<br>(0.494)                                 | <b>0.1681</b><br>(0.590) | 0.5148<br>(0.635)        | 0.0335<br>(0.039)         | 0.5038<br>(0.474)        | 0.0722<br>(0.595)        |                            | -0.0444<br>(0.522)       | 0.0501<br>(0.619)          | 0.1473<br>(0.610)          | 0.454<br>(0.652)           |
| ln_supplych     | 0.0761*<br>(0.041)                                 | 0.0576*<br>(0.034)       | <b>0.0445</b><br>(0.044) | 0.0752*<br>(0.038)        | 0.0482<br>(0.039)        | 0.042<br>(0.040)         | 0.0625*<br>(0.032)         | 0.0532<br>(0.036)        | 0.0506<br>(0.039)          | 0.054<br>(0.038)           | 0.0566<br>(0.041)          |
| ownership       | 0.1037**<br>(0.048)                                | 0.0768*<br>(0.042)       | 0.0663<br>(0.055)        | <b>0.0764*</b><br>(0.040) | 0.0533<br>(0.044)        | 0.0729<br>(0.050)        | 0.0595**<br>(0.027)        | 0.0628<br>(0.041)        | 0.0729<br>(0.050)          | 0.0781*<br>(0.043)         | 0.053<br>(0.046)           |
| ln_seller_share | 0.1016<br>(0.133)                                  | 0.0659<br>(0.126)        | -0.0051<br>(0.012)       | -0.0061<br>(0.011)        | <b>0.0697</b><br>(0.124) | -0.0015<br>(0.012)       | -0.0004<br>(0.011)         | 0.0018<br>(0.011)        | -0.0031<br>(0.011)         | 0.044<br>(0.124)           | 0.0858<br>(0.134)          |
| ln_ACQ          | 0.3076<br>(0.483)                                  | -0.0331<br>(0.534)       | -0.4118<br>(0.637)       | 0.0520*<br>(0.027)        |                          | <b>0.0359</b><br>(0.029) | 0.0283<br>(0.023)          | 0.1374<br>(0.519)        | 0.0034<br>(0.622)          |                            | -0.2519<br>(0.608)         |
| ln_period       | 0.032<br>(0.022)                                   | 0.0343*<br>(0.020)       | 0.0391*<br>(0.022)       | 0.0361*<br>(0.021)        | 0.0363*<br>(0.021)       | 0.0354<br>(0.021)        | <b>0.0391**</b><br>(0.019) | 0.0538**<br>(0.020)      | 0.0387*<br>(0.020)         | 0.0339*<br>(0.019)         | 0.0377*<br>(0.021)         |
| flex            | 0.0391<br>(0.053)                                  | 0.0137<br>(0.049)        | 0.0269<br>(0.042)        | -0.0136<br>(0.046)        | 0.0083<br>(0.046)        | -0.004<br>(0.046)        | 0.0544<br>(0.037)          | <b>0.0426</b><br>(0.040) | -0.0089<br>(0.043)         | 0.0011<br>(0.043)          | 0.0262<br>(0.040)          |
| LNG_distance    | -0.0000***<br>0.000                                | -0.0001***<br>0.000      | -0.0000**<br>0.000       | -0.0000***<br>0.000       | -0.0000***<br>0.000      | -0.0000***<br>0.000      | -0.0000***<br>0.000        | -0.0000***<br>0.000      | <b>-0.0000***</b><br>0.000 | -0.0000***<br>0.000        | -0.0000**<br>0.000         |
| PNG_distance    | -0.0001**<br>0.000                                 | -0.0002***<br>0.000      | -0.0001<br>0.000         | -0.0000*<br>0.000         | -0.0001***<br>0.000      | -0.0001**<br>0.000       | -0.0001***<br>0.000        | 0<br>0.000               | -0.0001***<br>0.000        | <b>-0.0001***</b><br>0.000 | -0.0000*<br>0.000          |
| year_dum        | -0.2122***<br>(0.061)                              | -0.1683**<br>(0.065)     | -0.1295*<br>(0.074)      | -0.1534***<br>(0.031)     | -0.1011*<br>(0.059)      | -0.1838**<br>(0.069)     | -0.1480***<br>(0.027)      | -0.1419**<br>(0.063)     | -0.1577**<br>(0.070)       | -0.1494**<br>(0.072)       | <b>-0.1437*</b><br>(0.073) |
| r2              | 0.73   | 0.77                     | 0.68                     | 0.68                      | 0.74                     | 0.77                     | 0.72                       | 0.69                     | 0.75                       | 0.75                       | 0.69                       |

\* p<0.1, \*\*p<0.05, \*\*\* p<0.01

- PNG\_Distance
- 0.01% decrease in price with 1km increase

# Discussion

## factors of negotiating

- Market structure : the characteristics of strategic significance of energy commodities including gas, and take into consideration of how such commodities are influenced by domestic market and corporate structure
- Transaction-specific : TOP provision or transaction costs arising from adjustments in renewal agreements are almost entirely levied on buyers.
- The Northeast Asian countries need to understand bargaining power under considering the market structure of their own countries and transaction-specific factors in the Northeast Asian market.