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Ensuring Energy Security beyond Conventional Boundaries

-Three essays on energy security with geopolitics, bargaining power and market structure-

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Abstract

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This study seeks to introduce a methodology for analyzing the fundamental cause of fossil fuel procurement in order to accurately explain the current phenomenon beyond traditional interdisciplinary boundaries. The concept of "non-traditional security" has gained increasing importance as the international community has begun to recognize that the promotion of security requires not only maintenance of territorial and military security of state but also safeguarding of human communities from all threats, including unconventional, non-military risks at the supra-, inter-, and intra-state levels.

It can be emphasized that energy security through the lens of human security focuses on spreading loss deeply and widely. In order to avoid energy insecurity, inter-state cooperation or supra-state actors are needed. Even though non-security issues have become increasingly common in almost all aspects of society, fossil fuel procurement remains an important goal of the nation-state. Furthermore, fossil fuel procurement results in geopolitics factors. This research aims to examine and explain the current state of fossil fuel procurement based on the understanding that there are overlapping perspectives regarding energy security between resource economics, international political economics, and geopolitics.

First, the research attempts to provide a rationale for comparing the options for potential pipeline construction in Northeast Asia, and to explain the debate about realistic options for Northeast Asia. In addition, the proponents of pipeline natural gas (PNG) gas supply have begun to recognize the significance of non-traditional issues, which require cooperation from each state to promote regional security, although traditional security concerns still dominate the agenda of governments in terms of access through territorial borders and route decisions. To consider the linkage structure, network game and the link-based flexible allocation rule are applied to determine the benefits and bargaining power of Northeast Asian pipeline construction options. This could establish that the pipeline linkage structure comprises different values depending on which country participates in the pipeline coalition comparing the value of each route, the value allocated to each country, and their relative bargaining power. Consideration of the first mover could explain the reason for selecting the Russia–China–South Korea route or the Russia–North Korea–South Korea route in the decision on Northeast Asian pipeline.

Second, this study attempts to identify the factors that determine the contract price of Europe's long-term contract, and to figure out to what extent this would affect the contract price. Gas sales and the purchase agreement are dealt with at the firm level, even though the characteristics of natural resources primarily represent a strategic or politicized commodity of the nation-state, making the contract price an issue that should be dealt with at the national level. This study introduces LASSO analysis and double selection in order to establish the factors among potential variables that determine the long-term gas contract price. This alternative approach is motivated to figure out the price-determining factors in bilateral long-term gas supply contracts that display high-dimensional data and that underwent difficulty in conventional estimation. With respect to bargaining power, the state of a consumer country's market structure is a pivotal factor responding to the supplier's priority in the bilateral long-term contract. The results of our study signify that there is a room for buyers to negotiate preservation of loss arising from transportation costs. Factors that are assumed to have influence over the bargaining power of supplier and consumer countries during negotiations inherently have geopolitical characteristics.

Third, this study attempts to determine the relationship between energy security and the institutional environment in the generation sector. It is an attempt to expand the security dimension to include intra-state energy delivery issues. The effect of liberalized restructuring—entry liberalization, privatization, and vertical divestiture—on the supply reliability in four separate sub-sectors of the electricity industry is evaluated empirically. This study attempts to establish how energy security is related to the restructuring of the electricity industry in the generation sector through the random effect model. Institutional change that is originally intended to enhance efficiency could depart from the initial goal in the generation sector.

Keywords: Energy security, Non-traditional security, Geopolitics, Bargaining power, Market structure

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Overall introduction

1. Backgrounds

Due to the uneven distribution of natural resources and their consumption, the issue of fossil fuel supply has always involved transportation. Energy security has been set as a major national policy goal of, in particular, regions in which the consumption of fossil fuel is concentrated, such as Northeast Asia. In terms of oil and gas supply, Northeast Asia has depended highly on crude oil and gas from the Middle East and liquefied natural gas (LNG) from Southeast Asia. The supply of Russian gas to Northeast Asian pipeline natural gas (PNG) market has heightened the expectations of Northeast Asian countries. With the emergence of a large-scale supply contract between Russia and China, a debate on the Russian PNG supply chain to Northeast Asia has also started to emerge. The core of the debate is about the supply route of Russian PNG to Northeast Asian countries, namely, Korea and Japan, and the specifics of these debates are even leading to political disputes.

The approach to Russian gas has given rise to the new task of negotiating the contract price of the new energy source in the long-term PNG contract. Importing countries that have the price formula on the JCC-indexed LNG long-term contract are now in need of extending their bargaining to the new PNG negotiation invitees. Attention to the contract through these negotiations has led to questions about the bargaining power of both sides. Interested parties have started to look carefully into the source of these negotiations, and the effects of bargaining power on the contracts. The contracts of European countries are benchmarked due to their active PNG trade and complex infrastructure.

Europe, being highly dependent on gas, has a long history of its natural gas market, and thus, has a complex supply chain, consisting of diverse importing and exporting countries. The geographic location of Western Europe, where major importing countries are concentrated, has made it possible for them to import gas through the gas fields of Russia, North Africa, and the North Sea, and therefore, these countries have imported PNG and LNG in various scales. Highly dependent on gas, Europe has faced the threat of a natural gas shortage, of which the Ukraine crisis is one example. Recently in the natural gas conflict due to Russian sanctions, Europe attempted to reduce its dependence on Russia with a policy on diversifying suppliers. The political dispute over the *Nabucco project* and *South Stream*, which started during a discussion on resource development of the Caspian Sea, has clearly shown how the issue of energy supply from geopolitics can become a conflict.

As seen from these examples, European gas supply and importing methods are directly linked to the issue of energy security, and this is deeply related to geopolitical factors. Ukraine and Belarus, located on the path from Russia to Europe as transit countries, have enjoyed their positions due to their strategical importance. The damage and threats from the Ukraine Crisis have come largely from geographic location. In addition, the dispute over the Southeast European routes for the Caspian Sea resources was apparent between Russia versus the US and EU, and this example shows the role of geopolitical factors in regulating access to resources. This aspect might also appear in Northeast Asia, and the relationship between importing and exporting countries might lead to an important issue for energy security.

As previously mentioned, energy security has been an important goal for policymakers. However, the use of this term by policymakers has been very abstract, and policies arising from this abstract concept often have been inconsistent or unsystematic. In response, an active discussion is taking place in the field of resource economics over the analysis and fundamental approach to the concept of energy security. The interest in energy security is being extended from the method of defining and measuring energy security to its various levels and context of analysis.

The concept and range of the term energy security are very dynamic, and are somewhat correlated to the value and history of a country. Even during the process of supply from procurement, transformation, generation (heat), and delivery all the way to consumption, energy security may appear in diverse forms. In addition, the interaction with the peripheral context may affect the level of energy security. In particular, the institutional environment of a society may affect energy security, apart from its initial goal of changing the previous regulations.

2. Energy security as non-traditional security

To discuss the concept of energy security, the four As (availability, affordability, accessibility, and acceptability) have been used by many scholars as a reference to help grasp essential characteristics in the history of energy security studies. Availability and affordability are considered mainly as targeted objectives in international organizations (EC, 2000; IEA, 2016) and form the core concept of energy security "as the uninterrupted availability of energy sources at an affordable price" (Jamasb & Pollitt, 2008; Yergin, 1988). With regard to availability and affordability, some scholars have used the general economic term "loss of welfare" (Bohi & Toman, 1993) to capture the cause of fossil fuel concentration (Lefèvre, 2010), and from a long-term perspective (Jansen & Seebregts, 2010).

The other two As, accessibility and acceptability, were connected to energy security in the 2007 APERC report. APERC used the four As, merging the classic "availability" and "affordability" with "acceptability" and "accessibility," respectively, to constitute a generic concept of energy security. Kruyt et al. (2009) classified indicators of energy security by the four As. Cherp and Jewell (2012) criticized this traditional classification scheme and suggested defining energy security as "low vulnerability of vital energy system" (Cherp & Jewell, 2014).

Alternative approaches proposed by Cherp and Jewell (2014) are useful for discussion in the context of non-traditional security in terms of being considered sectorally or geographically. They argue that it is not restricted to specific sectors, elements of supply chains, or issues and therefore, is flexible enough to be applicable to historic, contemporary, and future energy systems in diverse contexts (Cherp & Jewell, 2014).

Since the end of the Cold War and the start of globalization, an ever-changing world have been reshaping the way we regard security issues in the complex area of international relations. An inclusive concept for security is needed to figure out the combination of various growing actors, issues, and processes in international relations. The concept of “non-traditional security” (NTS) has gained increasing importance as the international community has begun to recognize that the promotion of security requires not only maintenance of territorial and military security of state but also safeguarding of human communities from all threats, including unconventional, non-military risks at both the inter- and intra-state levels (Caballero-Anthony & Putra, 2012; Lee, 2008).

For traditional realists, governments make a clear distinction between “high” and “low” politics for serving national interest, considering non-military issues as “low politics” (Hough, 2014). From this perspective, changing international relations highlights the appropriateness of discussing an agenda on non-traditional security as low politics by national policy decisions, beyond the military security area considered “high politics” (Lee, 2008).

The high-politics perspective—sticking to national security-prioritized military rather than non-military issues—was eventually contested as being too narrow (Caballero et al., 2006). Several security scholars have pointed out that non-military issues should also be securitized and framed as a matter of national security (Caballero et al., 2006; Hyun et al., 2000). Widening the concept of security is not simply a move to reconceptualize the meaning of national interests and reframe “high politics.” Rather, it is an attempt to expand the security dimension to include non-military threats to human communities (Caballero et al., 2006; Caballero-Anthony & Putra, 2012; Hough, 2014).

Caballero-Anthony and Putra (2012) emphasized energy security through a human security lens focusing on inter-state relations, governance, and socioeconomic impacts and underline the promotion of cooperation, especially fostering regional cooperation. The authors cover three interdependent levels in their discussion on energy security: international, national, and individual. At the national level, energy security is about the ability of the state to supply energy affordably, reliably, and sustainably. At the individual level, energy security is about the ability to maximize the economic utility of energy sources (Caballero-Anthony & Putra, 2012).

As non-security security issues have become increasingly common in almost all parts of society, to discern the NTS threats, there are some attempts in China to define energy security with new criteria, such as environmental, human rights, and institutional dimensions. This non-traditional energy security concept has its value and rationale and there is a growing body of literature on China's non-traditional energy security (Leung, 2011; Wang, 2005).

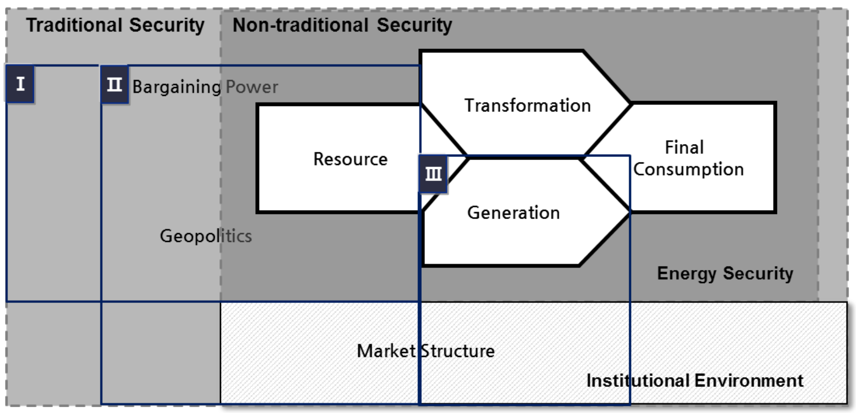
3. Research purpose

The current research starts with an interest in the issue of energy security. The purpose of this research is to examine and explain the current state of energy security based on the understanding that there are different perspectives on energy security between resource economics, international political economics, and geopolitics. First, the research attempts to provide a rationale for comparing options for the potential pipeline construction in Northeast Asia, and to explain the debate about a realistic route. Second, the research attempts to identify the factors that predict the contract price in Europe's long-term contracts, and to establish to what extent these would affect the contract price. Third, this research attempts to determine the relationship between energy security and the market structure in the generation sector.

4. Overview

This paper is seeking to introduce 'non-traditional security (NTS)' conceptualized as human security from all threats including non-military risks at the supra-, inter-and intra-state levels beyond the traditional security to maintain territorial and military security of state. Energy security can be recognized as human security highly related to human welfare in terms of its impact and harm in severity. For avoiding energy insecurity intra-state coordination, inter-state cooperation or supra-state actions are needed. That is, nation-state approach needs to be extended to intra-, inter- and supra-state in accordance with non-traditional security issues.

Even though non-security issues have become increasingly common in almost all parts of society, fossil fuel procurement still has been one of the important goals of the nation-state. Furthermore it results in the geopolitics factors that make energy security lies on boundaries between traditional issues. Energy security connotes geopolitics factors, holds bargaining power and interacts with market structure. This research is to examine and explain the current state of the issues based on the understanding that there are overlapped perspectives regarding the energy security between resource economics, international political economics and geopolitics.



	Traditional Security	Non-traditional Security	Energy Security
I	National boundary	Supra/Inter-state	Availability
II	National condition	Inter/Intra-state	Affordability
III	National management	Inter/Intra state	Reliability

Figure 1 Schematic overview

This study seeks to introduce a methodology to explain and analyze the fundamental cause of fossil fuel procurement in order to explain the current phenomenon accurately beyond traditional interdisciplinary boundaries. Essay Ⅰ analyzes the network games and allocation rule in order to determine the benefits and bargaining power of Northeast Asian pipeline construction options. It attempts to approach issues of energy security that may arise from the supply and demand of natural gas from a geopolitical perspective. Essay Ⅱ introduces LASSO analysis and double selection in order to establish the factors that determine the long-term gas contract price. It discusses geopolitical factors and bargaining power according to the market structure that is apparent in the long-term contract. Essay Ⅲ establishes how energy security is related to the restructuring of the electricity industry in the generation sector through a random-effects model. It discusses the effects of the change in the market structure, which were originally meant to enhance efficiency, on the original goal of energy supply.

Essay I.

Bargaining power in Northeast Asian pipeline options for Russian gas

1. Introduction

Due to Ukraine Crimea crisis in 2014, United States and EU imposed sanction against Russia which made it difficult for Russia to export gas towards Europe. Around 93% of total gas consumption in Europe is supplied through import, in which 33% of them are fulfilled through Russia's supply chain (IEA, 2015). Russia, the country where oil and gas export account for more than 50% of country's financial budget, have had an direct impact on economic system due to Europe's decreasing dependence on Russia's gas export by way of obtaining new supply sources.

In order to ease the fiscal crisis originating from tight export policy towards Europe, Russia attempted for expansion towards Northeast Asian market. The far-east region development has been planned as part of transformation policy towards "Look East Policy" which emphasizes cooperation with Asia-pacific region initiated by Putin. As a result, the far-east energy development has been realized via PNG supply contract between Russia and China in May 2014. Europe's sanction against Russia increased the significance of Northeast Asian market expansion for Russia, putting an end to gas supply contract stalemate between China and Russia. The contract includes natural gas supply of 38bcm per year starting from 2018, which accounts for 16% of annual export volume of Gazprom with $400 billion estimation.

Northeast Asian market is gaining a spotlight as an alternative to export towards Europe, and Korea and Japan participation is a key factor for the additional development in the following regions: Chayandinskoye field, Kovyktinskoye field, Sakhalin gas field. Thus, countries like Korea and Japan, where there are great demands for natural gas but dependence on import is large, have many options to choose in obtaining Russia gas supply. In parallel to LNG export, Russia is pushing towards diversification of export methods by way of expanding towards Northeast Asian Market. With Russia and China PNG supply contract being fulfilled, Korea and japan is also poised to consider Russia's PNG introduction.

PNG differs from LNG in that the contract is established in a long-term contract form due to following characteristics of supply chain. First, PNG supply is done by specifying the countries-in-demand along with gas field development and production. Also, pipeline construction should be accompanied with infrastructure construction. Moreover, stable demand is required for the contract. In contrast to LNG, where it can increase the flexibility on both supply-demand sides by delivering the gas via transportation usage in port and terminals, PNG demand region is fixed with specified supply gas-field and supply routes. Also, the possibility of alternative routes being cancelled would rise if PNG infrastructure construction for specific demand is done. As to say, PNG supply development is based on the particular demand, and determination of specific route rules out the other routes in consideration. Due to these kinds of PNG supply characteristics, country's location has always been a key factor in natural gas supply issue. Concentration of fossil fuel field in specific regions around the world, and the mismatch between the demand-supply regions made the need for the fossil fuel transportation. Among these, PNG is the supply form mostly affected by geographical location, and these kinds of characteristics can be seen in Europe where active PNG trade is conducted.

As mentioned earlier, Europe's gas reliance on Russia's gas supply reaches around 33% of total import, and in the case of PNG, this index is much higher, reaching 38% of total import. In case of Europe Continent where LNG barely exists, dependence on Russian PNG is very high. Especially, countries like Germany and the other Western countries where there are high demands for natural gas possess PNG supply route from Russia in which most of the old pipelines pass through Eastern Europe countries.

Among them, dependence on *Southern system* (which takes routes via Ukraine) was very high in which Russia-Ukraine gas dispute in 2005 causing serious threats to Europe's gas supply security. Hereupon an active discussion has been made for PNG routes that fulfills Europe's demand but detours Ukraine. As a solution, supply route that makes connection from Germany to Russia called *Nord Stream* has been constructed. The conflict between Russia and U.S-EU allies became much intense together with natural gas supply discussion.

Disputes regarding Caspian Sea natural gas development and PNG supply routes to

Europe continued because of geographical location and political situation in many countries involved. Diplomatic disputes could be seen represented by *Nabucco project* (Trans-Caspian Energy pipeline connecting U.S and EU countries) and *South Stream* (Pre-Caspian Energy pipeline). Here, political situation related to state interest originating from state's geographical location played a key role. *Nabucco project* has been suspended in 2013 due to disparity among exporting countries in the 2000s, and Russia made a decision to terminate *South Stream* in 2014 due to Europe's sanction against Russia. Thus, formation of energy transportation construction line is not only decided by bilateral contract but also requires participation of states that the pipeline needs to be installed. In other words, gas pipeline supply contains the location of natural resource field and demand regions, and location of transit country. Above mentioned disputes regarding *Nord Stream* construction between Germany and Russia, as well as *South Stream* & *Nabucco project* shows how state's interest could differ according to pipeline route installment. In other words, state's interest varies according to participation of specific countries in pipeline supply chain, together with existence of alternative route and determination of specific routes. This shows that pipeline indicates positional power of specific states, making it necessary to understand positional power revealed in diplomatic disputes.

As mentioned above, pipeline structure shows strategic relationships amongst the states because it possess specific transportation infrastructure. Many countries related to natural gas supply pipeline would participate, and the costs and benefits involving the construction would be allocated to those countries involved. In this procedure, state's bargaining power would depend on how the pipeline is installed. In this paper, review on pipeline linkage structure through network analysis would be done, and the bargaining power of the states through positional power would be examined through this analysis.

Attempts to analyze each state's bargaining power through pipeline network have been assorted through application of network theory to natural gas supply issue. In this paper, network game would be used as an approach to analyze gas supply pipeline linkage structure, and review on advantages of using this approach would be done by differentiating it with other game.

Also, model for Northeast Asian pipeline construction option would be provided. In Section 2, review on PNG route option in Northeast Asian countries would be done and alternative option would be introduced as a comparable option in this research. In Section 3, pipeline option would be structured into network game, and allocation rule would be provided in order to judge bargaining power of each country. In Section 4, the result of Link-based Flexible Allocation Rule application and deducted conclusion of bargaining power of each country is indicated, and in Section 5, discussion on the meaning of geopolitical implication and the energy security in Northeast Asia PNG would be shown based on these results.

2. Supply chain and bargaining power

Northeast Asian countries also have begun to recognize the significance of non-traditional, low-politics issues in promoting regional security, although traditional security concerns still dominate the agenda of the governments in the region. In terms of energy security, traditional and non-traditional issues are overlapped. This aspect result from primarily characteristics of natural resources which represent strategic or politicized commodity of nation-state (Shin,2011). This factors are augmented in Northeast Asia where 20th century territorial boundaries are drawn. On the other hand, promoting cooperation could achieve common solution to solve energy supply and get the benefit through sharing the value of network. Still, promoting regional economic cooperation has been difficult because each nation is at a significantly different stage of economic development and liberalization. Furthermore, no regional institution has yet taken on any central coordinating responsibility in East Asia(Lee, 2008).

Although the diplomatic, political, economic, legal and environmental aspects of these pipelines, pipeline plans and related conflicts have been extensively explored in works such as Jentleson (1986), Gost(2004), Stern (2005), Victor et al. (2006), Finon and Locatell (2008) and Shiobara (2007), the previous literature has not been able to provide a formal model-based analysis to determine why these conflicts took almost two decades to overcome(Nagayama&Horita,2014).

Hubert and Ikonnikova(2004) and Hubert and Suleymanova(2008) were appraised of the first quantitative study of power relations in Northwestern European gas supply chains using cooperative game theory. Hubert and Ikonnikova(2011) make more realistic model with cooperative approach in terms of assumptions for gas supply contract avoiding inefficiencies and demonstrate power endogenously from role in gas production and transport. Hubert and Ikonnikova(2011) employ cooperative game in characteristic function form, use Shapley value for calculating the value allocated and make a notion of "Reletive Shapley Value" to represent the change caused by change in pipelines.

Since Shapley(1953) and Shapley and Shubik (1954) offer a method for the a priori evaluation of the division of power among the various bodies and members, cooperative notions enter into a picture of political science. Shapely value is considered as a tool for analyzing the power structure in cooperative games. Applications include internal telephone billing rates (Billera et al., 1978), water infrastructure (Suzuki & Nakayama,1976), central facilities for profit centers (Young, 1985), and ATM Networks (Gow & Thomas,1998). Most of this literature is normative, explaining how cost should be allocated (Hubert & Ikonnikova, 2011).

While Hubert and Ikonnikova (2011) use the Characteristic Function Form Game as the model and the Shapley Value as the solution concept, Nagayama and Horita(2014) employ Network Game and Link-based Flexible Network Allocation Rule. Network game and family of allocation rules are proposed by Jackson (2005) taking the view of network as not a permanent fixture.

Nagayama and Horita(2014) provide results that are significantly different from Hubert and Ikonnikova (2011) explaining the prolonged conflict between Russia versus Ukraine and Belarus. The former can focus on the transit countries' bargaining power with essential position, whereas the latter emphasize the producer's power amongst players in the coalition. Thus, the former can forecast that the Western Europe would get the benefit from Nord stream, which is directly connected between Russian and Western Europe, and it can explain the direct pipeline implemented by joint project.

Curraini et al. (2015) examine why and how network economics would be an effective conceptual and analytical tool to analyze infrastructural networks in the access to and use of natural resources such as oil and natural gas. The pattern of pipelines determine the cost and benefits from the use of the resource through which this is sourced and distributed. Two issues seem to be of prominent interest for the application of network economics to natural resources: how players will share the gains from cooperation through bargaining, and how this will affect, and be affected, by the degree of flexibility of the network and the incentives to form and delete links (Curraini et al, 2015).

In the context of international politics, there are network theoretical approaches to Northeast Asian supply chain focusing on the PNG pipeline linkage. Shin(2012a, 2012b) is attempt to figure out effective networking strategy, background to construct eastern energy supply network and impact of the Russia - North Korea - South Korea PNG project on energy security and power network in the perspectives of the global network politics theory. From this research, Russia’ s energy supply network will strengthen its influence, more specifically hard power in Northeast Asia. Furthermore, it will also increase its positional network power as soft power which can bring redress of power balance in the region (Shin, 2012b)

3. Pipeline options for Russian gas

In the past 10 years when gas supply contract between Russia and China was in a stalemate, most of the gas supply in Southeastern Coast, the region where there is mass gas consumption of China, was fulfilled through import via LNG Terminal in Southeastern Coast. PNG in China was provided through existing West-East pipeline from Xinjiang to Beijing and Shanghai. Expansion of gas supply plan in western area by reaching towards resources in CIS region through Turkmen-Uzbek-Kazakh Pipeline construction, or introduction of Russia gas as a solution to increase in gas demand in eastern area was in a stalemate in the past ten years. However, gas supply contract between Russia and China enabled PNG supply from Heilongjiang in China. Agreement on this contract increased the possibility of Altai pipeline contract establishment between Russia and China, which signaled gas cooperation between those countries. In case of Russia-China eastern route, the agreement on the contract was settled in May, 2014, and the supply would start from 2018. The pipeline within Russia which reaches 4000km, is designed in a way where it can supply maximum of 61bcm per year. Long-term PNG export contract with China enabled Russia to develop Kovyktinskoye field and Chayandinskoye field, the key far-east development region in Russia, and this helped realizing construction of ‘Power of Siberia’. Also, the possibility of expanding routes towards South Korea and Japan becoming as one of the alternatives to Northeast Asian countries’ gas supply chain became high.

Power of Siberia would primarily build up Chayandinskoye field-Khabarovsk-

Vladivostok (3200km) Line in Yakutia and is planned to finish at the end of 2017. Kovyktinskoye field in Irkutsk region would be linked to this line, and transferred at the border from Blagoveshchensk to Heihe in China. Gas pipeline would include Daqing-Harbin-Shenyang-Dalian route, and Shenyang-Beijing-Shanghai route. Thus, up to 13bcm additional supply is possible, and provided this amount of additional supply is transferred through China to South Korea, the final destination in Russia would be Blagoveshchensk. In case of routes to North Korea, final destination of additional volume would be Vladivostok (the final destination that link from Blagoveshchensk to Khabarovsk and all of these would be handed over to North Korea from here. Pipeline within Russia includes pipeline construction option that links Korsakov, the southern area in Sakhalin, to Japan.

The task of Russia's PNG introduction through South Korea initiated in the early 1990s together with Yakutia gas field development discussion. Together with development cooperation in Chayandinskoye field in Yakutia and Kovyktinskoye field in Irkutsk region, discussion on Russia-China-South Korea Line and Russia-North Korea-South Korea Line were done in order. In the early 2000s even the research on feasibility of Kovyktinskoye field development and Russia-China-South Korea route were conducted. However, this attempt failed due to the failure of United Gas Supply System (UGSS) by Russian government and the failure of Russia to negotiate price with CNPC together with the Gazprom's opposition to Kovykta gas field export volume.

In 2002, Russia-North Korea-South Korea route that does not pass through China has been proposed by Putin, and through the summit between Roe administration and Putin administration in 2004, transportation of the oil field and gas field in the far-east has been discussed. The possibility of realizing the installment of gas pipeline that goes through North Korea was high in 2004, but no advancement has been made due to nuclear test in North Korea and strain relationship between North Korea and South Korea in 2009, just before final contract in 2010. Russia-North Korea- South Korea route has been resumed in 2011 by North Korea – Russia summit, but no conclusion was made with it. By large scale contract between Russia and China in May 2014, South Korea was in dominant position in that in took advantage of Russia-China-South Korea route, the cost effective way to transfer gas. The discussion on South Korea-North Korea-Russia route was resumed as the one of those unification policies. Thus in this paper, comparison between Russia-China-South Korea route and Russia-North Korea-South Korea route would be dealt as an important pipeline construction option.

The option for Russia to link gas pipeline to Japan without transiting any countries is to link Korsakov in Sakhalin to Hokkaido. In case of making Honshu as a final destination, coastline and overland route is in consideration. In case of coastline, discussing is being delayed due to fishery rights and environmental problem. In case of coastline, the plan is based on construction plan of private company suggested by Russia-Japan natural gas supply committee of council member. In this research the cost was calculated based on the coastline route, the option where much more specific cost is available compared to the overland route. In case of gas supply option by transiting states, Russia-China-South Korea-Japan route and Russia-North Korea-South Korea-Japan route could be considered, and in these kinds of cases, the offshore line connecting Busan in South Korea to Kita-Kyushu in Japan. The cost of this route has been theoretically provided by Asakura (1996), and the cost was calculated based on this paper.

Eastern Gas Program was order by the Russian Industry and Energy Ministry as the state-run Development Program in September 2007 for an integrated gas production, transportation and supply system in Eastern Siberia and the Far East, taking into account potential gas exports to China and other Asia-Pacific countries. The Program stipulates that together with gas production centers (Yakutia, Irkutsk, Sakhalin Region and the Kamchatka Territory) and the unified gas transmission system formation (Power of Siberia and Sakhalin-Khabarovsk-Vladivostok Gas Transmission System). Gas from the Chayandinskoye field will flow into the Power of Siberia gas pipeline starting in 2018, which will connect the Irkutsk and Yakutia gas production centers in 2022 and transport natural gas from both centers to the Russian Far East and China.

Sakhalin II project, Russia's first liquefied natural gas (LNG) plant, became operational in 2009. Gas from the Sakhalin III project forms the main resource base for the 'Sakhalin–Khabarovsk–Vladivostok' gas transmission system. Commercial production started in 2014 from Krinskoye field and planned to be brought online in 2021 from Yuzhno-Krinskoye. Sakhalin I project operated by Exxon Neftegas Limited began production at the Arkutun-Dagi field to export. After passing the LNG Export Liberalization Law in November 2013, put an end to Gazprom's monopoly, allowing Novatek and Rosneft to export liquefied natural gas.

PNG sources considered in this paper are Chyandinskoe, Kovyktinskoye and Sakhalin field of which considered Sakhalin III as main source with pipeline to Vladivostok. Eastern gas program unifies these three fields with integrating transmission system formation in the long-term. It can be a reason that Russia is considered as one node in Northeast Asia pipeline network. Gazprom set Sakhalin III gas field supply source when Russia-North Korea-South Korea route were considered (KEEI, 2014). This fact implicates Sakhalin field can be managed in integrated system to export. This is the reason why pipeline linkage between Russia and Japan, which would be recognized geographically separated, need to be considered in Northeast Asian pipeline network. In short, Far-east Russian PNG sources in this paper operated together by Gazprom appointed by the Russian Federation Government as the Eastern Gas Program execution coordinator.

Based on the obtainable route information in Northeast Asian countries following route has been planned indicated in the figure Ⅰ-1 and table Ⅰ-1 below. Some starting line and ending line could be linked to the other starting-ending points. Those kinds of routes that were never discussed due to technical problem and political issue despite the fact that physical linkage is possible, is ruled out in this research. For example, linking Russia and Korea through East Sea or linking China and Japan through Yellow Sea kind of concept is physically possible, but since the possibility of realizing this scheme is shallow, thus, it has been ruled out from this research. Regarding specific linkage routes and network information consisting of each country’s participation would be dealt in 4.3.

Figure Ⅰ - 1. Pipeline route for Northeast Asia

Table Ⅰ - 1. Intercountry PNG Route

Gas field	Route	Link	Link name
Kovyktinskoye field, Chayandinskoye field	Kovyktinskoye field(Irkutsk) - Chayandinskoye field(Yakutia) - Skovorodino - Blagoveshchensk - Khabarovsk- Vladivostok - Blagoveshchensk - Chinese border - Heihe (Heilongjiang) - Daqing - Harbin - Shenyang -Dalian - Shenyang - Beijing - Shanghai	Russia-China	RC
Kovyktinskoye field, Chayandinskoye field, Sakhalin	Vladivostok - North Korean border - Pyeongang	Russia-North Korea	RKp
Kovyktinskoye field, Chayandinskoye field, Sakhalin	Blagoveshchensk - Chinese border - Heihe (Hei longjiang) - Daqing – Harbin - Shenyang - Dalian – Yellow Sea - Pyeongtaek	China-South Korea	Ckr
Kovyktinskoye	Pyeongang - South Korean border - Cheolwon		KpKr

field, Chayandinskoye field, Sakhalin	- Incheon - Pyeongtaek		
Kovyktinskoye field, Chayandinskoye field, Sakhalin	Busan - Kitakyushu	South Korea-Japan	KrJ
Sakhalin	Okha - Korsakov - Ishikari - Tomakomai - Hachinohe - Sendai - Hirono - Hitachi - Kashima	Russia-Japan	RJ

4. Model

4.1 Network game

Recently, there has been a discussion on gas supply route as Northeast Asian pipeline gas has risen as a new market for Russian gas. Complex European pipeline network has been a main research item, making it a good benchmark for Northeast Asian pipeline connection structure. As Russian gas supply via Belarus and Ukraine takes over 40% of EU countries in-demand, focus on transit countries' bargaining power based on geographic location has been made. Conflict of negotiations on price and transit fee between Ukraine and Russia in 2009 has made state of suspension in gas supply, which shows the re-evaluation of transit countries' position (Currarini et al., 2015).

Hubert and Ikonnikova (2011) approached this issue with cooperative game using characteristic function form and made an attempt to analyze power structure of natural gas supply chain. Pipeline supply chain is based on the participation of each country as a composition of pipeline coalition, and modeled the interdependence of the supply chain in the value function form through cooperative game. Value function is calculated based on cost information of each pipeline and the profits based on hypothetical demand. The game result is based on the allocation of each country's total profit, and the allocated value is interpreted as a bargaining power of each country in coalition (Hubert & Ikonnikova, 2011). In this research, the attempt to comprehend the power structure through cooperative game when pipeline coalition is formed. Modeling cooperative game enabled the approach towards power structure within the coalition even without the knowledge of the negotiation procedure.

In Hubert and Ikonnikova (2011), the well-known solution of cooperation game, Shapley Value, Core, Nucleolus, is deducted to show each country's bargaining power in the coalition. This kind of coalition game in characteristic function form game cannot reflect connection structure between the players. Myerson (1977) suggested communication game which put into consideration of players' connection within the coalition, and deducted Myerson value from Sharpley value. Coalition value is based on communication game by reflecting the existence of linkage between the players, and here, Jackson and Wolinsky(1996) suggested network game by adding linkage structure with Myerson value. In network game, value function is defined towards network, and it is reflected in the value function on how the coalition is linked with each other (Jeon & Heo, 2006).

Previous paper is based on the value allocation of players in the network. Borm et al. (1992) suggested position value by substituting link to players. Also, whereas Myerson value assumes network as fixed one, Jackson (2005) viewed network as a flexible one by taking into consideration of alternative network. Here, he suggested player-based flexible allocation rule and link-based flexible allocation rule. Nagayama and Horita (2014) pointed out that characteristic function form coalition game does not reflect the network externalities in Hubert and Ikonnikova (2011) due to the unique value allocation to coalition.

When value function is determined as the unique value in characteristic function form, externality (which can be affected through the network formation among the states) cannot be reflected. In case of Northeast Asian countries, the game participants like Russia, China, South Korea, and Japan could be formed into different network such as ‘Russia-China-South Korea-Japan’ or ‘Russia-China South Korea and Russia-Japan’. As to say, in case of ‘Russia-China-South Korea’, different value is allocated to them based on how Japan would be linked to these countries, which could be seen as an example as a network externality. In coalition form, the value given to {Russia, China, South Korea, Japan} is specified as unique value, which could not be seen as reflecting externalities. In difference to coalition form game, network game could evaluate the players’ bargaining power based on network structure by reflecting on network externalities.

Nagayama and Horita (2014) made use of link-based flexible network allocation rule in network game, and analyzed the bargaining power of each country in Russian gas supply pipeline network that is transmitted through Ukraine and Belarus. In characteristic function form game and communication game, grand coalition or complete network is required to be efficient one, but the network game and the flexible network allocation rule could assume the incomplete network as the efficient one and the flexible network allocation rule could allocate the value among the link just like the position value.

4.2 Allocation rule

Let $N = \{1, \dots, n\}$ denote a set of players. A network g is defined as a set of unordered pairs of players $\{i, j\}$ where $\{i, j\} \in g$ indicates that i and j are linked in the network g. For notational simplicity, let ij represent link $\{i, j\}$. The set of all unordered pairs within N is denoted by g^N, and the set of all networks on N is denoted by $\mathrm{G} = \{g | g \subseteq g^N\}$. Links can be either added or deleted from the network. We denote the network that results from adding a new link ij by $g + ij$, and the network that results from deleting a link ij by $g - ij$. A value function for network g is a function $v : G \rightarrow \mathbb{R}$, and the set of all possible value functions is denoted by V (Jackson, 2005; Nagayama & Horita, 2014). Given a value function v, the monotonic cover $\hat{v}$ is defined by

$$\hat{v} = max_{g' \in g} v(g \quad) \quad \cdots\cdots \text{Eq. (I-1)}$$

According to Jackson (2005), an allocation rule is the way in which the value generated by a network is allocated among the players, either through decisions or perhaps even by some outside intervention. An allocation rule is a function $\mathrm{Y} : \mathrm{G} \times \mathrm{V} \rightarrow \mathbb{R}^n$ such that $\sum_i Y_i(g, v) = v(g)$ for all v and g. Jackson (2005) introduces the solution concept of flexible networks. An allocation rule Y is a flexible rule if $Y_i(g, v) = Y_i(g^N, \hat{v})$ for all v and efficient g relative to v. A network $g \in G$ is efficient relative to value function v if $\mathrm{v(g)} \geq \mathrm{v}(g')$ for all $g' \in G$. Thus, efficient networks are value-maximizing networks(Jackson, 2005; Nagayama & Horita, 2014). The Link-Based Flexible Network Allocation Rule is defined as

$$Y_i^{LBFN}(g, v) = \frac{v(g)}{\hat{v}(g^N)} \sum_{j \neq i} \left[\sum_{g \in g^N - ij} \frac{1}{2} (\hat{v}(g + ij) - \hat{v}\,(g)) \left(\frac{\#g! \left(\left[\frac{n(n-1)}{2} \right] - \#g - 1 \right)!}{\left[\frac{n(n-1)}{2} \right]!} \right) \right] \quad \cdots\cdots \text{Eq. (I-2)}$$

where #g denotes the number of links in g. Relative bargaing power proposed by Hubert and Ikonnikova(2011) can be defined as follows. Since the value of a given network is v(g) and the allocation of value to a given player i is $Y_i^{LBFN}(g,v)$, the Relative Bargaining Power of player i is defined as

$$RBP_i^{LBFN}(g,v) = \frac{Y_i^{LBFN}(g,v)}{v(g)} \quad \cdots\cdots \text{Eq. (I-3)}$$

4.3 Game setup

As mentioned above, purpose of this paper is figuring out bargaining power on each pipeline option based on how it is compulsory in the network game framework. Link-based Flexible Allocation Rule is used for evaluating bargaining power from not coalition but linkage structure, which means how links are differently connected under same coalition. Thus, the main part of analysis is comparing value of each route, value allocated to each country, and relative bargaining power. Each PNG route is designed to scenario which includes links to make network. Each country decides to participate in the network as link with neighbor country.

The six links which compose Network in each scenario are Russia-China(RC), China-South Korea(CKr), Russia-North Korea(RKp), North Korea-South Korea(KpKr), South Korea-Japan(KrJ) and Russia-Japan(RJ). Each scenario postulates network composed of coalition of links. All scenarios are presumed Russia to be a supplier and China, South Korea and Japan to be importers. 7 scenarios is built according to participation of importers and linkage structure of each link. The route of each scenario is shown in Table as follows.

Hubert and Ikonnikova(2011)and Nagayama and Horita(2014) presupposed that quantity passing through the pipeline is changing as route or link added. These can be possible because PNG supply quantity is big enough to run the various route for demand and adding route can expand demand and supply quantity in European market. However, PNG demand is not realized yet in Northeast Asian market, thus, parallel route is less likely to be considered. This situation makes fixed demand quantity reasonable in the scenarios. Demand for China is designed 38 bcm as same as contract quantity in 2014 and one for South Korea and Japan is set for 10bcm and 20 bcm repectively, which is arranged in the several feasibility study. Thus purpose of participating to network means to meet the fixed demand of gas as already sets. North Korea participate in the network as only transit country. This analysis has a different signification from previous literature in terms of comparing each scenarios designed to meet the same demand quantity.

Status quo is the first link for PNG supply in Northeast Asia that planned to supply gas after 2018. This scenario is set to be called '*Status quo*' since it is realized and under construction. Russia and China participate in the network with RC link in this scenario and 38 bcm is supplied from Kovyktinskoye field and Chayandinskoye field.

West Stream configures demand for South Korea to be met through China. RC and CKr have linkage to make pipeline network. CKr link is designed as to be started from Blagoveshchensk with newly constructed pipeline not from Dalian. This set-up makes scenario reasonable since existing RC link is constructed with piping design system fitting demand for China, thus not allowing demand for South Korea transport through RC link. To delivered 10 bcm for South Korea new pipeline construction is needed from Blagoveshchensk. Russia move 48 bcm from Kovyktinskoye field and Chayandinskoye field to Blagoveshchensk to supply gas through *West Stream*.

Bypass literally means bypassing North Korea with RC, CKr, and RJ. This scenario has its name after European '*Bypass*' that made a detour around Ukraine to deliver gas from Russia to Germany. It has similar meaning in terms of bypassing the one that has high risk country. RC and CKr is same as *West Stream* and RJ is supplied with 20 bcm from Sakhalin field.

West-expanded is added with KrJ, link between South Korea and Japan, to *West Stream*. According to increasing supply quantity Russian has to provide China, South Korea and Japan through power of Siberia with 61 bcm, maximum quantity of Kovyktinskoye and Chayandinskoye field, adding 7bcm from Sakhalin field.

North Stream transfer demand quantity for South Korea via North Korea compared to *West Stream* having China as transit country. It contains linkage with RC, RKp and KpKr. Russia supply 48bcm from Kovyktinskoye and Chayandinskoye field for cross-border transfer at Blagoveshchensk to China(38bcm) and at Vladivostok to North Korea(10bcm). North Korea participate in this network as transit country transporting 10 bcm to South Korea.

Each represents network connecting Russia with importers repectively with RC, RKp,KpKr and RJ. Each shows network with all countries as does in *West-expanded* and

North-expanded, however it has different linkage structure. Thus, it is realized that network game has advantage compared to coalitional game or communication game. Kovyktinskoye and Chayandinskoye field(48 bcm) and Sakhalin field(20bcm) are sources for China(38bcm), South Korea(10bcm)(via North Korea) and Japan(20bcm) respectively.

North-expanded extends *North Stream* to Japan with adding KrJ. Demand for South Korea and Japan pass through Korea peninsula compared to *West-expanded*. All country has connection with RC, RKp, KpKr and KrJ. Russian gas is delivered at Blagoveshchensk to China(38bcm), Vladivostok to North Korea(30bcm) and Busan to Japan(20bcm) from Kovyktinskoye and Chayandinskoye field(61bcm) and Sakhalin(7bcm).

Exp-Korea is composed of RC and RJ except Korea peninsula. 38 bcm is provided to China from Kovyktinskoye and Chayandinskoye field, and 20bcm is done to Japan from Sakhalin. It only shows that Russia is directly connected with importers.

As each scenario shows, there is different network made by different linkage structure with same participating nations. Each scenario reflects network structure which has different linkage. It is more realty that grand coalition and complete network is not the most efficient, thus, alternative network (eg. *Bypass* is alternative for *West Stream*) which could form in the supply chain need to be included in the network game. This is a reason why Link-Based Flexible Network Allocation Rule is selected for allocating value in the network game.

Table Ⅰ - 2. PNG Route Scenarios

Scenario	Route	Link involved	Gas field
Status quo	Kovyktinskoye field(Irkutsk) - Chayandinskoye field(Yakutia) - Skovorodino - Blagoveshchensk - Khabarovsk- Vladivostok - Blagoveshchensk - Chinese border - Heihe (Heilongjiang) - Daqing - Harbin - Shenyang -Dalian - Shenyang - Beijing - Shanghai	RC	Kovyktinskoye field, Chayandinskoye field
West Stream	Kovyktinskoye field(Irkutsk) - Chayandinskoye field(Yakutia) - Skovorodino - Blagoveshchensk - Khabarovsk- Vladivostok - Blagoveshchensk - Chinese border - Heihe (Heilongjiang) - Daqing - Harbin - Shenyang -Dalian - Yellow Sea - Pyeongtaek - Shenyang - Beijing - Shanghai	RC, CKr	Kovyktinskoye field, Chayandinskoye field
Bypass	Kovyktinskoye field(Irkutsk) - Chayandinskoye field(Yakutia) - Skovorodino - Blagoveshchensk - Khabarovsk- Vladivostok - Blagoveshchensk - Chinese border - Heihe (Heilongjiang) - Daqing - Harbin - Shenyang -Dalian - Yellow Sea - Pyeongtaek - Shenyang - Beijing – Shanghai Okha - Korsakov - Ishikari - Tomakomai - Hachinohe - Sendai - Hirono - Hitachi	RC, Ckr, RJ	Kovyktinskoye field, Chayandinskoye field, Sakhalin

	- Kashima		
West-expanded	Kovyktinskoye field(Irkutsk) - Chayandinskoye field(Yakutia) - Skovorodino - Blagoveshchensk - Khabarovsk- Vladivostok - Blagoveshchensk - Chinese border - Heihe (Heilongjiang) - Daqing - Harbin - Shenyang -Dalian - Yellow Sea - Pyeongtaek- Busan - Kitakyushu - Shenyang - Beijing - Shanghai	RC, CKr, KrJ	Kovyktinskoye field, Chayandinskoye field, Sakhalin
North Stream	Kovyktinskoye field(Irkutsk) - Chayandinskoye field(Yakutia) - Skovorodino - Blagoveshchensk - Khabarovsk- Vladivostok - North Korean border - Pyeongang - South Korean border – Cheolwon - Incheon - Pyeongtaek - Blagoveshchensk - Chinese border - Heihe (Heilongjiang) - Daqing - Harbin - Shenyang -Dalian - Shenyang - Beijing – Shanghai	RC, RKp, KpKr	Kovyktinskoye field, Chayandinskoye field
Each	Kovyktinskoye field(Irkutsk) - Chayandinskoye field(Yakutia) - Skovorodino - Blagoveshchensk - Khabarovsk- Vladivostok - North Korean border - Pyeongang - South Korean border – Cheolwon - Incheon	RC, RKp,KpKr, RJ	Kovyktinskoye field, Chayandinskoye field,

	- Pyeongtaek - Blagoveshchensk - Chinese border - Heihe (Heilongjiang) - Daqing - Harbin - Shenyang -Dalian - Shenyang - Beijing – Shanghai Okha - Korsakov - Ishikari - Tomakomai - Hachinohe - Sendai - Hirono - Hitachi - Kashima		Sakhalin
North-expanded	Kovyktinskoye field(Irkutsk) - Chayandinskoye field(Yakutia) - Skovorodino - Blagoveshchensk - Khabarovsk- Vladivostok - North Korean border - Pyeongang - South Korean border – Cheolwon - Incheon - Pyeongtaek – Busan – Kitakyushu - Blagoveshchensk - Chinese border - Heihe (Heilongjiang) - Daqing - Harbin - Shenyang -Dalian - Shenyang - Beijing – Shanghai	RC, RKp, KpKr, KrJ	Kovyktinskoye field, Chayandinskoye field, Sakhalin
Exp-Korean	Kovyktinskoye field(Irkutsk) - Chayandinskoye field(Yakutia) - Skovorodino - Blagoveshchensk - Khabarovsk- Vladivostok - Blagoveshchensk - Chinese border - Heihe (Heilongjiang) - Daqing - Harbin	RC, RJ	Kovyktinskoye field, Chayandinskoye

	- Shenyang -Dalian - Shenyang - Beijing – Shanghai Okha - Korsakov - Ishikari - Tomakomai - Hachinohe - Sendai - Hirono - Hitachi - Kashima		field, Sakhalin

4.4 Calibration

The link-specific transportation cost per unit of gas T_{ij} is defined according to the calibration by Hubert and Ikonnikova (2011) and Nagayama and Horita(2014). The total cost of transporting gas (T_{ij})can be decomposed into capacity cost $(c_{ij})$and operating cost(m_{ij}) consisting of management & maintenance cost. To calculate the total cost, we suppose the total cost of supplying and transporting gas to a point y is $T(y)$. The increase in cost from transporting it a little further is proportional to $c + m + g \cdot T(y)$. Thus, we solve $T' = c + m + g \cdot T$, use $T(0) = MC_0$ and deduct the initial value MC_0 to obtain the formula(Hubert & Ikonnikova, 2011). Each term is estimated for every possible link separately using estimated data from feasible study for certain routes.

$$T_{ij} = \frac{(c_{ij}+m_{ij}+g_{ij}MC_0)(e^{gl}-1)}{g_{ij}},\ MC_0 = 11 + 0.8x \quad \cdots\cdots \text{Eq. (I-4)}$$

As mentioned above, capital cost and operating cost(including m&m cost) are based on the feasible studies(Russia Petroleum, CNPC & Kogas(2003);Gazprom and Kogas(2010); Kogas(2016); JPIC(2015)) and estimation (Asakura(1996)) by theorectical assumption. In previous papers referred, for existing pipelines for Western Europe (South, Yamal 1) capacity cost are sunk and can be ignored in the analysis. On the other hand, All options are not completed, thus, capital cost is calculated for all link with net present value with discount rate. This is reason why old pipelines in the Europe starting from Russia have no depreciation reserve as its lifetime elapsed. Meanwhile pipelines for Northeast Asia is not realized yet, therefore, cost of all options can be compared. 25 years denotes the expected lifetime of the facilities and r=0.1 is the assumed interest rate for investment. Capital cost and operating cost include pipeline, managing facilities, compressor station, storage facilities and heating value controller. Operating cost is calculated certain rate of capital cost in the feasibility studies.

With difficulty to access cost information on Russian gas field, Hubert and Ikonnikova(2011) derive marginal production cost based on rational assumptions. They assume a comparatively low intercept(11$/tcm) from old gas field and high slope(0.8) making South and Yamal 1 optimal when assumed low intercept. Hubert and Ikonnikova(2011) justified a steep increase of cost with very high cost of the development of new fields like Yamal or Shtokman. We assume that Far-east gas field shows similar level with new ones of west Russia.

Power compressor stations is used for keeping the gas moving. A certain fraction g is included in the gas supplied. We assume $g = 0.25/100km$ for all onshore pipelines, and offshore ones, which needs much higher pressure for its offshore section, has $g = 0.5/100km$.

Table Ⅰ - 3. Specification of links

Links	Investment Cc [$/tcm]	O &M m [$/tcm]	Compressor gas g [%/100]	Length l [100km]	Quantity Supplied x [bcm]
RC	31.6	0.06	0.25	53.7	38

RKp	17.7	0.16	0.25	10.52	10
Ckr	69.9	0.35	0.5	20.92	
KpKr	2.3	0.45	0.25	2.15	10
KrJ	3	0.9	0.5	2.1	20
RJ	31.3	0.9	0.5	13.50	20

In table Ⅰ-3 CKr present the highest capital cost as calculated. Since new pipeline is needed from Heihe to South Korea border contrary to expectations to connect line from Dalian, the length of this link is extended than expected. China domestic pipeline was planned with no consideration of transporting gas for South Korea and Japan which needs to be wider diameter and designs higher pressure. KpKr and KrJ shows lower capital cost by short length. Meanwhile RJ including long offshore distance presents higher capital cost.

In operating cost, RCh has the lowest cost among links. While onshore pipeline for large supply quantities make the cost per unit lower than others, offshore such as KrJ and RJ has much higher cost than onshore ones. Though CKr is offshore pipeline, it shows low operating cost by shallow water depth of Yellow Sea and easier operation than any other offshore pipeline.

38 bcm is applied for demand quantity for China as Russia-China contracted in 2014. South Korea and Japan demand 10bcm and 20 bcm respectively as feasible studies estimated.

Value of coalition is created when each country participates in the pipeline coalition and makes a link. Jackson (2005) mentions that the value function may involve "⋯both costs and benefits, and thus can be interpreted flexibly". Taking advantage of this flexibility, the utility functions $u : G(N) \rightarrow R$ for each link ij in the network are defined, and the value function is defined as the sum of these utility functions(Nagayama & Horita, 2014).

$$u_{ij} = px - T_{ij}x_{ij}\ ,\ v(g) = \sum_{ij} u_{ij}(g) \quad \text{Eq. (I-5)}$$

The price p was set at a fixed price of 350$/tcm, based on the estimated contract price for Russia and China which will be traded since 2018. This paper did not assume the price of natural gas as being determined according to the total quantity traded in the pipeline network as did in Hubert and Ikonnikova (2011). Rather, the Relative Bargaining Power calculated from the model affected the price negotiations. Generally natural gas price in the bilateral contract for PNG long-term supply is on the table. It concludes with pricing formula composed of indexed price. The change of price indexed to oil product, crude oil and natural gas hub price consists pricing formula, but it is restricted as certain weight also being negotiable. Long-term PNG contract price shows less volatility than other product. This is reason why long-term contact secures the more stability on supply. Furthermore, if Russia-China contract price is estimated by neighbor countries, the price for these countries with same supplier could not break the certain bounds. The more information on the contract price, the more narrow bounds. Thus, fixed price is used for comparing scenarios.

Table Ⅰ - 4. Specification of scenarios

Scenario	Links	Investment	O &M	Compressor gas	Length	Quantity Delivered
		cC [$/tcm/100km]	m [$/tcm]	g [%/100]	l [100km]	x [bcm]
Status quo	RC	0.59	0.06	0.25	53.7	38
West Stream	RC	0.59	0.06	0.25	53.7	48
	CKr	3.34	0.35	0.5	20.92	10
Bypass	RC	0.59	0.06	0.25	53.7	48
	Ckr	3.34	0.35	0.5	20.92	10
	RJ	2.32	0.9	0.5	13.50	20
West-expanded	RC	0.59	0.06	0.25	53.7	68
	CKr	3.34	0.35	0.5	20.92	30
	KrJ	1.41	0.9	0.5	2.1	20
North Stream	RC	0.59	0.06	0.25	53.7	48
	RKp	1.68	0.16	0.25	10.52	10
	KpKr	1.09	0.45	0.25	2.15	10
Each	RC	0.59	0.06	0.25	53.7	38
	RKp	1.68	0.16	0.25	10.52	10
	KpKr	1.09	0.45	0.25	2.15	10
	RJ	2.32	0.9	0.5	13.50	20
North-expanded	RC	0.59	0.06	0.25	53.7	68

	RKp	1.68	0.16	0.25	10.52	30
	KpKr	1.09	0.45	0.25	2.15	30
	KrJ	1.41	0.9	0.5	2.1	20
Exp-Korean	RC	0.59	0.06	0.25	53.7	38
	RJ	2.32	0.9	0.5	13.50	20

5. Results

5.1 Value allocated

Network value increased when the additional link took place with participation of the other players, compared to *Status quo*. Through this we can find the form of cooperative game in which the players heightened the coalition value by cooperating with each other. Moreover, compared to *West Stream* (participants of three countries: Russia, China, and South Korea), *West-expanded* value was much higher with additional participant: Japan. Compared to *Exp-Korean* (participants of three countries: Russia, China, and Japan), *Bypass* value was much higher with additional participant of South Korea. Also, compared to the other scenarios, the value in *North-expanded* and *Each* was shown to be the highest with all countries participating scenarios. Each country could create value in the cooperative form by participating in the certain routes, and they could heighten the network value through this behavior.

Table Ⅰ - 5. Scenarios, Capacities, and Value

	Supply Capacity [bcm/a]							
	Status quo	West Stream	Bypass	West-expanded	North Stream	Each	North-expanded	Exp-Korean
R,C	38							
R,C,Kr		48						
R,C,J								58
R,C,Kr,J			68	68				
R,C,Kp,Kr					48			
R,C,Kp,Kr,J						68	68	
Value %	32	45	92	64	50	100	99	73

The maximum network value was realized through *Each*. Compared to *West-expanded* and *North-expanded*, the scenario in which the all of the countries-in-demand participate in the coalition, the *Each* value was much higher. The reason why *Each* value was higher than *West-expanded* is because of the fact that CKr cost is expensive compared to the cost transiting North Korea. The reason why the *Each* value was shown to possess the higher value compared to the *North-expanded* value would be due to the fact that the cost linking direct gas pipeline from Sakhalin to Japan is much lower compared to the cost of transferring the gas by transiting Korea peninsula. The network value was shown to be much higher when all the countries participated in the game compared to *Status quo*.

The maximum value of Russia could be realized in *Each* due to the fact that the state could avoid the value allocation with transit-states by linking the pipeline directly to the country-in-demand. In other words, Russia could take all the network value that increases through the link addition.

China could realize its maximum value in *Bypass*. The reason why *Bypass* value is higher compared to *West-expanded* route is due to the fact that RJ route is cheaper compared to CKr link for Japan to import the volume. Thus, the effect of the lower cost value is much higher than positioning Japan as the lower-stream state.

Table Ⅰ - 6. Value allocated by country

	Value %				
	Russia	China	North Korea	South Korea	Japan
Status quo	34	50	-	-	-
West Stream	44	70	-	14	-
Bypass	93	100	-	20	96
West-expanded	53	90	-	48	20
North Stream	47	62	32	20	-
Each	100	88	45	24	100
North-expanded	74	87	100	100	38
Exp-Korean	79	75	-	-	86

In case of South Korea and North Korea, the value allocation from *North-expanded* is much higher compared to other scenarios. This is because North Korea and South Korea play a role as a transit country only when Japan exists as a lower-stream state: thereby being recognized as the essential country to linkage. In case of South Korea, the value allocation is much bigger in *North-expanded* compared to *West-Expanded* due to the fact that Ckr cost is expensive. North Korea could only obtain value allocation when it is participating the coalition, and in order to do this North Korea should play a role as a necessary link that transports demands in South Korea. The reason why *Each* value is higher compared to *North Stream* is in the fact that *Each* value being assumed to the efficient link.

Japan could obtain highest value allocation from *Each* by linking directly to Russia and not sharing the value with transiting countries. In case of Japan, either *Bypass* or *Exp-Korea* (direct route to Russia) was shown to possess higher value allocation compared to *West-expanded* or *North-expanded* (with South Korea, North Korea, and China as upper-stream state). Provided that Japan puts into consideration of upper-stream states, *North-expanded* allocates more values compared to *West-expanded*. This is due to the fact the Ckr cost is higher than Rkp and Kpkr.

5.2 Relative bargaining power

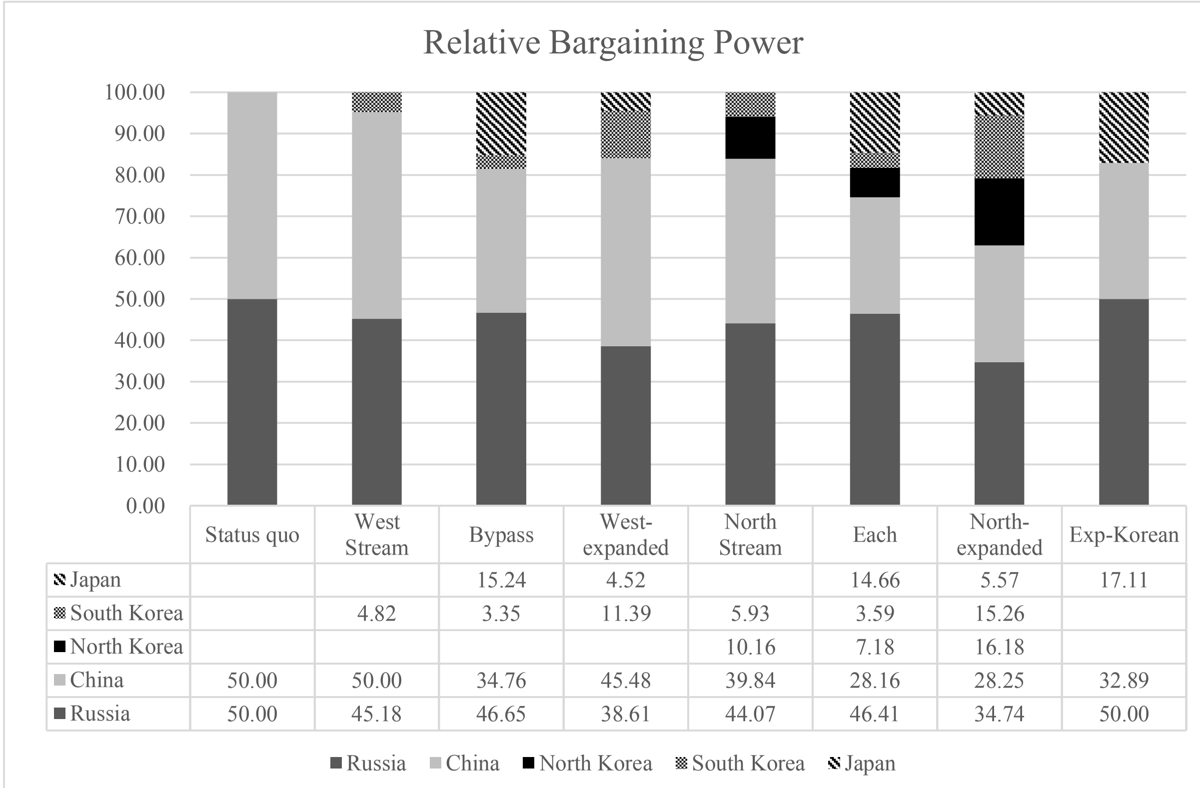
As mentioned above, Relative Bargaining Power(hereinafter RBP) indicates the share of each country possesses in each network scenario. The allocated value to the country differs based on the marginal contribution of each country because the necessity of each country varies based on the network structure. As a result, relative share is allocated differently in the network, which can be seen as a relative bargaining power. Through this, the analysis on the power structure within the network can be done regardless of the total value of the network. Basically, the necessity of a country is based on the geographical location, in which the network structure form makes geographic locational importance different.

In case of Russia, RBP was shown to be the highest when it halved the link value like *Status quo* and *Exp-Korean*. In case of an attempt to heighten the network value through the participation of the other countries-in-demand, the RBP in *Bypass* was shown to be the highest. This is because of the fact that Russia could take all of those value that it had to allocate between North Korea and South Korea in the *Each*, and *North-expanded* or the value that needs to be allocated to South Korea in *Bypass*.

China achieves maximum RBP in *West Stream* due to the fact that China is at the center of the network. In *Bypass* where China could possess maximum value, its RBP is relatively weak compared to *West stream* or *West-expanded*. This is due to the fact that China is relatively positioned off-the-center and cannot be recognized as upper-stream state of Japan.

In case of South Korea and North Korea, RBP was shown at the maximum rate in *North-expanded*. This means that they could heighten both RBP and value allocated only when Japan is designated as a lower-stream state. RBP in both states is shown to be the lowest in *Each*, which is the result of South Korea being the final state-in-demand.

In case of Japan, the highest RBP is shown in *Exp-Korean*. The reason why RBP is shown to be the highest for Japan is due to the fact that the value it takes from the link is big by connecting with Russia directly. Japan as the only state with *Status quo* achieves highest value.



	Status quo	West Stream	Bypass	West-expanded	North Stream	Each	North-expanded	Exp-Korean
Japan			15.24	4.52		14.66	5.57	17.11
South Korea		4.82	3.35	11.39	5.93	3.59	15.26	
North Korea					10.16	7.18	16.18	
China	50.00	50.00	34.76	45.48	39.84	28.16	28.25	32.89
Russia	50.00	45.18	46.65	38.61	44.07	46.41	34.74	50.00

Figure Ⅰ - 2. Relative Bargaining Power by country

5.3 Possible options with first mover

When determination on Ckr linkage is shown beforehand, with RC being fixed as Status quo, Bypass scenario is shown when Japan's participation is via RJ, and West Stream scenario is shown when via KrJ. Between two scenarios, possibility of Bypass scenario (the one with high link value and RBP) being chosen would be high. In this case, compared to West Stream (the scenario where Japan's decision not being made) decrease in RBP would result in China and South Korea. However, Bypass scenario is the one where China takes the maximum value. Thus, provided that Japan chooses RJ, it would be the best scenario in both maximum value and RBP aspect.

With RC being Status quo, when RKp link is determined beforehand, Each scenario would be shown in case Japan's link is RJ, and North-expanded scenario would be shown in case of KrJ. Between these two options, it is likely that Japan would choose RJ scenario, the one with high link value and high RBP. In this case, the value allocation rises compared to North Stream. But, the RBP in Each would decrease for China, North Korea, and South Korea compared to North Stream. In case of China, RBP in Each would drop slightly, but allocation value would rise by small margin compared to North-expanded. In case of South Korea and North Korea, the allocation value in Each would drop sharply compared to North-expanded, and the RBP would drop accordingly.

In case where RKp & KpKr is determined before anything else, the possibility of North-expanded (which is advantageous to both North Korea and South Korea) being chosen by Japan is low, and it is likely that Each scenario would be chosen, the one that links the country one by one. Even when there is no participation of Japan, the value allocation of Russia-North Korea-South Korea route and RBP is high. However, when there is participation of Japan, Russia-North Korea- South Korea route would be chosen rather than the Russia-China-South Korea route due to the high possibility of RJ, making Each scenario the second best choice.

When RJ is determined with RC being Status quo, South Korea would decide Ckr which would be shown to be Bypass or RKp, KpKr would be determined which would be shown to be Each. In case of South Korea, allocation value and RBP in Each would be high compared to Bypass, making it likely to realize Each scenario. Thus, it would be advantageous for South Korea to position North Korea as an upper-state rather than China. In case of Japan, RBP in Each decreases compared to the case in Exp-Korean, but allocation value is shown to be the highest among the scenarios.

When taking into consideration of first mover, the reason why decision on Northeast Asian pipeline would relate to the selection of Russia-China-South Korea route and Russia-North Korea-South Korea route could be explained. In case of Japan, possessing RJ link alone is advantageous. If other states participate in the network, realizing Each through Russia-North Korea-South Korea route would be better for Japan. In case of South Korea and North Korea, the second best way is to realize Each through Russia-North Korea-South Korea. It is advantageous for China to fulfill West Stream or Bypass through Russia-China-South Korea route. In other words, the possibility of discussion leading to Bypass or Each is likely in possible scenarios, and the main decision making depends on Russia-China-

South Korea route and Russia-North Korea-South Korea route.

6. Discussion

6.1 Network game and Northeast Asian power game

Network power can be generated from the network structure that includes number and formation of links with postion of nodes. The concept of network power does not predicated on the properties of nodes themselves or the resources that nodes possess. Rather, network power means the power originated from the relations among nodes (Kim, 2008). In this paper network power can be interpreted as positional power that stems from postion of certain country in the network. According to this approach, network game extends to power theorectical implication. In this context, this paper pays attention to theories of positional power concerning structural attributes of networks and actor's positional roles given by such structural conditions beyond resource power of states possing endowment or inherent characteristics (Kim, 2011).

The discussion on PNG route has continuously been made after the long-term gas supply contract between Russia and China. This is due to the fact that there has been the accordance in interest between the supply states and in-demand states to increase the total profit through participation of Northeast Asian countries based on the gas supply volume via developed gas field. The result shows that there is an increase in network value in the other scenarios compared to Status quo, which explains why there has been an on-going discussion among the other states in Northeast Asian countries after the contract being made between Russia and China.

There has been research on feasibility of various alternative routes that could get Russian gas supply together with the gas field development in Russia's far-east region, but no decision have been made on routes that links through South Korea to Japan.

The pipeline coalition that can be seen in Northeast Asian region could affect the value allocation to the states within the network based on the selection to linkage. This was pointed out as the network externality, and in case of Northeast Asian region, network game approach has been the useful method to reflect network externalities. Inspection through the case where first mover is inserted, the result shows that the value allocation to China and South Korea varies based on Japan's choice when Russia-China-South Korea route and Russia-North Korea-South Korea route is chosen by South Korea. This means that the pipeline linkage structure makes the value different alongside with which country participates the pipeline coalition. Therefore, network externality is one of the factors to generate positional power.

Relative bargaining power imposing network externality was derived as solution of network game reflecting dominant positional power. Network game that reflects network externality is a useful framework to explain power game in Asian region. Russia as supplier and China, South Korea and Japan as buyer, North Korea as transiter maximise their positional power as making linkage and participating in the colition. These actors seek to hold network structural power beyond resource possessing power. It can be achieved through strategic order of linkage. It is advantageous for China to choose Russia-China-South Korea route to heighten its bargaining power and increase value allocation regardless of Japan's choice. Thus, the reason why China suggests South Korea to prolong pipeline could be explained through this. In case of South Korea and North Korea, it is advantageous for the countries to position Japan as a lower-stream states in order to increase value allocation or strengthen bargaining power. But in reality, this scenario is barely discussed in Northeast Asian countries, and the difficulty to discuss on this scenario through network game has been explained: It is advantageous for Japan to link directly with Russia in any cases, thus making it difficult to realize Expanded scenario.

In case of Russia, it opens all the possibilities on gas supply routes to in-demand countries due to the fact that value allocation volume increases as the number of participation state increases. Russia possessed maximum network value when linked to all the states individually, and the bargaining power increased as there were only few transit countries. In other words, it is likely that Russia would prefer to link routes individually with the other states, and in case of demand in South Korea, value when transiting North Korea route was shown to be the higher which makes it preferable for Russia to choose route transiting North Korea. In fact, Russia has shown the will towards transiting North Korea by suggesting North Korea to reimburse the loan or lowering the risk towards transportation to North Korea.

As a result, an important decision making in Northeast Asian pipeline network is the selection of Russia-China-South Korea route and Russia-North Korea-South Korea route, which is also a political issue being debated in South Korea when taking into consideration of PNG. The issue regarding South Korea and North Korea is not only the matter of the both states, but also the issue for the participating states of the pipeline coalition, which are the member of 'Six-party Talks'. Relative bargaining power as solution of network game can be an approach that provides implication on Northeast Asian power structure and changing international relations with interpreting positional power. Inspection through each state's interest on Russia-North Korea-South Korea route through network game, there would be no reason for Russia, North Korea, South Korea, and Japan to oppose this choice, and since this contradicts with China's interest, it is likely that China would continuously suggest routes transiting their country.

6.2 Geopolitics of energy security

This research was to compare and evaluate Northeast Asian pipeline construction options that have risen together with the gas contract between Russia and China. Understanding the power structure among the states that lies within the linking structure has been conducted by evaluating the bargaining power and the value allocation to each country based on pipeline linking structure. The pipeline infrastructure construction is dependent on geographic condition, and with supply and demand being specified, it is inevitable that the power structure is created within the coalition. It would be not enough to evaluate only the economic aspect, the cost and benefit from the pipeline contract to understand this. In this research, the difference in bargaining power in each state depending on geographic location (upper-stream state and lower-stream state) could be found through pipeline linkage structure model through network game.

In fact, a discussion on importing Russian gas to South Korea through pipeline has been made by comparing Russia-China-South Korea route and Russia-North Korea-South Korea route. In this case, not only the cost-efficiency should be taken into consideration but also the power structure within the pipeline network and the bargaining power difference emanating from it should be considered. As the result shows, South Korea's bargaining power varies depending on Japan's existence as lower-stream state. Also, China's bargaining power varies as well based on the existence of South Korea and Japan as the lower-stream state. As a result, if the choice of each state is based on the cooperation to enlarge the network maximum value, the cooperation between the states during the negotiation procedure could vary based on the bargaining power difference due to linkage structure.

As a characteristic of fossil fuel production, the resource is geographically concentrated in specific region. Due to the discordance in demand and supply, the issue of energy transportation arises which affecting the energy security in supply-side term. In case of supply of natural resources, especially the fossil fuel, the geographical location of supply states and demand states becomes the key factor. Especially, when it comes to pipeline transportation form, actual physical linkage is being created, making it difficult to avoid energy security issue and geopolitical issue. Energy transportation issue through pipeline is sometimes being affected by political decision making or sometimes affects the other way round. The network game and network allocation rule that was used in this research could be the useful tool in understanding the strategic relationship among the states that lies within the natural resource supply issue.

Essay II.

Price determinant factors in the natural gas contract

1. Introduction

In Northeast Asia, wherein LNG (Liquid Natural Gas) trading has thus far remained an exclusive domain of trade, the comprehensive pipeline natural gas supply agreement between Russia and China has increased the possibility of PNG trading. As the pipeline has been connected from Khabarovsk to Vladivostok, in tandem with the Russia's development in the Far East region, the possibility of PNG supply to the Korean peninsula has opened up, as well as the possibility of PNG supply to Japan through the La Pérouse Strait, as the pipeline also extends to Korsakov in Sakhalin and Vladivostok. Russia's entry into the Northeast Asian gas has marked the beginning of an alternative form of transportable gas in the region where only LNG trade has existed. The previous chapter discussed the route options for the new PNG trade in Northeast Asia and for this chapter, the gas price each country may face is examined when an actual sale and purchase agreement is made.

In general, LNG trading contracts in Northeast Asia have been in the form of long-term contracts, using a formula linked to JCC prices. The advent of the possibility of the new PNG trading, requires each state actor in Northeast Asia Each to understand the price levels that need to be updated and can be offered, all the while hoping that the price level of PNG will be comparatively advantageous to that of LNG. In addition, the discussion can be further made about the edge as the new consumer and the newly found bargaining power, which includes the contractual benefits of adding PNG trade, over Russia.

European gas market, where both PNG and LNG trades frequently occur, serves as a good example for understanding various properties found in gas contract. Its examination will increase the understanding of the characteristics of the gas contract and the power dynamics of negations between the supplier and consumer, through identifying the main factors that influence the determination of gas prices in contract and the extent to which such influence impacts such decision.

The purpose of this study is to understand the influence of each factor in determining the price by identifying the pricing determinants, and at the same time establish a predictive model of the price agreed in long-term gas supply contracts in Europe. The determination of a price agreed between the contracting state parties is generally not disclosed to the public, which presents a challenge to attain information on the agreed price level. On the contrary, the potential factors that may affect the agreement is a lot more at hand, which gives rise to the importance of the methodology of an approach for this study.

In Section 2, the elements of long-term gas contract in Europe are discussed. The causes and characteristics that appear in the long-term contract are observed followed by a discussion on the determination of the prices in the contract. Section 3 proposes a methodology for the identification of factors that affect the prediction of prices and the price levels found in long-term contract in Europe. The results are described in Section 4 and section 5 includes the discussion on energy security and bargaining power in negotiating prices.

2. European long-term gas supply contract

2.1 Long-term contract

In general, natural gas sale and purchase agreements are mostly comprised of long-term agreements. Development and production of gas fields are only push forward after specifying the demand and the volume of the demand, because they entail high costs. Since the long-term security of demand is essential to preserve these costs, the pervading form of agreements have been long-term. Particularly in the case of PNG, the infrastructure of a pipeline, which takes up a huge proportion of the cost, involves a fixture that ensures a stable supply of a large amount of materials inevitably has taken the form of a long-term supply. The development of gas fields with a specific demand in mind and the characteristics of infrastructure are attributable to the necessity of bilateral contract. Suppliers have an obligation to supply specific quantities for the specified price in the contract and the consumers are obliged to receive a certain amount at the agreed price. Unlike other products, in the supply agreement of natural gas there are additional specific conditions, such conditions deciding how to share the commercial risk between the bilateral parties (KEEI, 2005).

The conditions of long-term bilateral contract can be examined in terms of transaction costs. Long-term contract acts as factor in reducing the size and duration of the transaction costs in and of itself by ensuring the long-term demand for the supply amount of the gas. Maintaining a certain quantity of supply with a certain country over a long period of time means reducing the need for finding new consumers or to negotiate the price, which can lower the transaction costs. TOP (Take-or-Pay) provisions are present in terms of long-term contact that lays out obligations for consumer's commitments to the agreed amount for which, regardless of the supply and demand situation, the consumer is obliged to receive and pay, with the aim of sharing transaction costs that may occur in long-term contract.

The typical natural gas contact is renewed every 2 to 3 years in order to reflect changes in prices for it is a long-term ones, which can be viewed as another condition that determines how the risks would be shared (Goldberg&Erickson, 1987). Typically, the price agreed appears in a formula that is linked to the prices of other fuel sources, and it is negotiated through a renewed agreement in response to the changes in the prices of other fuel sources. In this way, renewed contract can be highlighted as a factor of transaction cost that accompany the price adjustments and negotiations.

That is, the sale of natural gas is accompanied by the cost which allows for the supply, so the long-term agreement itself will take the form of reducing transaction costs, and the conditions of long-term contract are for sharing the burden of transaction costs involved in ensuring bilateral obligation of supply and demand for a specified quantity (Neuhoff &Hirschhausen, 2005)

2.2 Indexation and contract price

Determination of the price level of natural gas has been proposed in two approaches. First approach is to identify contract price level in a cost-plus basis, in respect to the seller wanting to preserve the production cost. To supply natural gas, a process of exploration, development and production of gas is required, which means initial capital cost for the seller, and subsequent floor of the price of natural gas is determined by adding some profit to such supplier's costs. Second approach is the net-back value approach, which stipulates that the ceiling price of the natural gas in the natural gas contract is determined at the level competitive to other products (market substitute value) minus the cost of consumer directly supplying to the demand market.

The contract price is determined at any level between these price ceiling and floor, a decision that sets the seller and the buyer profit, and this is when the bargaining power of each party comes in hand. In cases of trade agreement of the natural gas, as previously mentioned, it is difficult to expect the operation of the 'invisible hand', which determines the level of demand and supply, since that is determined by the two parties of the negotiation. Rather, the potential for the act of a 'visible hand' is more likely since the distinctive conditions of trade inherent in natural gas render the difference in bargaining power between sellers and buyers effective in determining the level of their profit.

In the past, the price of natural gas generally took the form that is linked to the price of crude oil. There are many causes to this, mainly crude oil trade has taken precedence in the world market so it makes sense to utilize crude oil price as a credible source for determining price of natural gas, and also the development and production of natural gas is usually accompanied by crude oil and the price level for natural gas that preserve such costs inevitably is linked to the price of crude oil(Buchanan et al., 2008). More recently, with the advancement of gas trade hub attributable to the increase in supply and demand of natural gas worldwide, and the subsequent development of spot market, there is a trend that the trade of natural gas and its price is determined by its own value (Stern & Rogers, 2011)

Along with the changes in the market conditions, there have been attempts to increase the ratio of linkage to the hub price and reduce the linkage to the existing crude oil in renewing long-term natural gas contract. After recession in 2008, excessive supply of natural gas to Europe brought down the spot market price. Brent-oil price decreases 17.98 $/mmbtu in 2008 to 14.7$/mmbtu in 2010 as NBP hub price showed more gap between 10.79 $/mmbtu(2008) and 6.56$/mmbtu(2010) (OECD/IEA,2012). As expansion of spot market, 26% market share with 4%p increase in 2009 (Lewiner(ed.),2009). Along with spot market price decline, European demand countries holing long-term contract required hub-indexed pricing to suppliers.

As mentioned, there is a need to reflect the price changes during the long-term contract that average more than 20 years in the natural gas price formulas, and this necessity has induced the use a form of agreement that reflect such changes relative to the price of certain product. In Europe, linked indicators for determining the contract price of natural gas generally have been crude oil prices or petroleum products that act as substitutes in the consumer market. However, with the recent spot market development, the dependence on existing indicators linked to conventional crude oil or petroleum product prices has been reduced and the ratio of linking to the spot price of natural gas has been rising in an effort to put a price on the value of natural gas itself.

The various transactions involving PNG and LNG in Europe use diverse linked indexation to determine the price level of natural gas. It was observed that the higher the ratio linked to the crude oil, the higher the price levels of natural gas, and the higher the dependence on spot-indexed, the lower the price levels. The development of spot market since 2010, coupled with the tendency of the spot price of natural gas being lower than crude oil, gave rise to a demand for increasing the ratio of spot-indexed price in determining prices, whether it be for renewing existing long-term contract or negotiating new long-term contract. Acceptance of such a request from a seller is manifested differently from contract to contract, because deciding the ratio of linked index favorable to the buyer is influenced by the bargaining power of the parties involved. The focus of this study is not the linked index itself, but rather which factors influence both parties to determine a which specific ratio of the linked index to use and how this decision affects the contract price. To put it differently, answering questions such as what are the factors that determine the bargaining power of the supplier and consumer state actors and how much influence such power wields over the contract price is the focus of the discussion for this study.

3. Model

3.1 Data overview

This study surveyed seven consumer countries receiving the European LNG and PNG and the source of supply was separately identified as PNG or LNG. The number of combinations between supplier and consumer countries was a total of 28, and the data was collected from two annual periods of the year 2010 and 2014. As mentioned, renewing the long-term contract to reflect changes in price occurs at a two or three-year intervals, the year 2014 was chosen to avoid the three-year period following 2010, during which most forms of agreement that took place were renewals of existing contract.

Table Ⅱ- 1. 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	
Italy	Russia, Netherlands, Norway	Qatar, Algeria
Netherlands	Russian, Norway, UK	
Spain	Norway, Algeria	Qatar, Algeria, Nigeria
United Kingdom	Norway	Qatar

For the price data, a speculative data on contract price published by WGI based on price formula estimation through linked index was used. Contract price corresponds to the typical cross-border transactions, and also includes long-term commitments, and where possible, transactions between private entities (corporations). By default, it was based on a survey of the trading prices for such entities of the consumer and supplier countries. This pricing data should be assumed to reflect the changes in linked indexes and should be regarded as the estimated results of applying such changes in pricing formula within contract.

Data on consumer countries was collected from the IEA and OECD, and matters related to the contract from WGI natural gas weekly, Woodmac database, DIW Berlin (2015), resources from corporations, and media via internet search. For the distance data, World LNG shipping distance map of LNG Insight was utilized, and for the distance of PNG, publicly disclosed route distances specified in contract were used.

3.2 Variables

As mentioned in the introduction, gas prices through long-term contract are influenced by not only the value of the gas itself but also by numerous other factors. Even in cases of inter-corporation transactions, the characteristics of the country are inherently reflected, and it is also worth noting that the geographical impact is more pronounced in natural gas as opposed to other products. This study presents such factors that affect contract price according to four categories, which are market specific determinant, transaction-specific determinant, cost determinant, and demand determinant. The objective of such classification is to reflect the factors suggested by previous studies and to classify them, and each factor may be interpreted in terms of other categories.

3.2.1 Market-specific variables

The parties of gas contract could assess their respective comparative advantage according to the conditions of the market, which can be deemed as dependent on the structure of the gas market (NBER,1990). Often the term goes the seller's market or the buyer's market, which indicates the relative position of the supplier or the consumer in the region where there is a market demand (region market). If the supplier has more quantity and higher ratio, the supplier has a comparative advantage in the market, in which case the supplier has the bargaining power to drive up the price(Knittel, 2003). The variables that represent such case are “seller pw to World” and “seller pw to EU,” representative of the ratio of the supplier’s share in the global market share and the European market, respectively. It is calculated by the ratio of the supplier’s supply in respect to the quantity of the demand in the region. In contrast, if the consumer country has more quantity and higher ratio, the consumer has a comparative advantage in the market. “Buyer pw to World” and “buyer pw to EU” represent the ratio of consumer country’s quantity demanded of the respective market. In addition, if the consumer has a various sources of gas supply, it will lessen its dependency on the contract with a particular supplier, and therefore its bargaining power on price will rise(NBER,1990; Neuhoff &Hirschhausen, 2005). On the other side of the coin, if sources of supply are so varied that the quantity received from any particular supplier is low, the consumer may not enjoy the lowering of price that comes with increasing quantity.

In the supply and demand of natural resources, sellers generally tend to have the upper hand, and if the history is any indicator, there have not been many instances where buyers had the comparative advantage. Buyer countries usually demand lower prices from seller countries based on price-lowering factors during contract price negotiations, and this is when the market and corporate structure of the buyer country serve as a window as to how much of an incentive the corporation in the buyer country has. Market structure is a variable that represents the market structure of the buyer country, which reflects the ratio of the largest corporation's market share in the gas industry. This ratio, published by the OECD regulation database through scaling was used for the purpose of this study. Ownership is directed towards showing the ownership structure of the buyer country's corporation, and in the case of public operator can be less vulnerable than the private operator, but there can also be fewer incentives for lowering prices(Reymond, 2007). This is because the loss of profit stemming from a high-priced agreement can be alleviated by each shareholder through a shareholders' agreement, and their accountability to the price level in the gas contract is weak. State-owned enterprises are also related to the ownership structure and pertain to whether or not they are government-owned. A government-owned enterprise can have incentives to determine the contract price of gas by factors other than the value itself due to government policies.

3.2.2 Transcation-specific variables

The presence of transaction costs, as previously discussed, is one of the reasons attributable to the long-term gas contract. Transaction costs can occur in the context of the supply, transportation and agreement and such transactions costs may be a factor in determining the contract price. Seller share is a variable that represents the ratio of the quantity supplied of the supplier country to the consumer country's quantity demanded. If the ratio of the quantity supplied from a particular supplier to the quantity imported from certain countries is high, it can lower the transaction costs when using transportation network, renewing or negotiating new contract. Comparably, buyer share variable represents how the transaction costs can be reduced if the ratio of a particular consumer country's quantity imported to certain countries' quantity exported is high.

ACQ variable represents the annual commitments between both parties of the seller and buyer and it can lower transaction costs if the quantity agreed is sufficiently high, which can be conducive to bargaining for a lower price when entering into an agreement(Goldberg&Erickson, 1987). Firm import share refers to the ratio of a particular firm's share to the total amount of quantity imported of a consumer country, and when such ratio is high it can act as a factor in lowering transaction costs within the buyer country. The Flex variable refers to the instance where there is provision for flexibility of quantity in gas supply contract, as a more specific variable for transaction costs arising from the quantity supplied(Neuhoff &Hirschhausen, 2005; Asche et al., 2002). Flexibility of quantity can be expressed in various terms, but for this study, it was used to distinguish the instances when Take-or-Pay were mentioned from those not mentioned and aimed to measure it as a dummy variable. If the adjustment of TOP was mentioned, it was assumed that it was due to the need for the flexibility of quantity supplied and thus parameterized.

Period represents the years lapsed since the sales and purchase agreement, and longer the years lapsed, the shorter the remaining period of contract. In general, a buyer country is less incentivized to drive renewal negotiations for a price level or linked index more favorably for the buyer country, the shorter the remaining time of the contract. This is because in seller-dominant gas supply contract, renewing an agreement entails transaction costs, most of which are borne by the buyer country(Goldberg&Erickson, 1987).

In supplying gas, transaction costs can occur in transportation, especially in the case of PNG gas trade. Due to pipeline infrastructure, it is inevitable to avoid transit state, and the more transit states there are after crossing the border of the supplier country, the higher the transaction costs. In a typical PNG trade, there is usually a firm in charge of transportation, and such firm enters into contract with transit states on crossing borders, and the buildup of transportation contract raises transportation costs. There may also be increased risks involved with a higher number of transit countries itself, and although such risks may never materialize, they can nonetheless become factors that increase the transaction costs and subsequently, the contract price. In order to specify variables involving the risks of transportation, Ukraine dummy was included to indicate whether the transportation passed through Ukraine where actual disrupt of supply took place(Reymond, 2007). Dummy variable that distinguishes PNG and LNG was included to confirm whether there is a difference of contract price between PNG and LNG.

3.2.3 Cost variables

Contract gas prices, as previously mentioned, essentially is determined at the rate that preserves the production costs and producers' profit, and consumers are faced with importing country's border price, which includes transportation costs and transit fees (in the case of PNG) on top of the contract price. The farther the distance it takes for the importing country to receive the gas, the higher the transportation costs and transit fees are, inevitably hiking up the price when it reaches the final consumer, in which case the buyer can be induced to match such a price to those of other competitive fuels or prices in other countries by demanding lower contract price (Maxwell&Zhu, 2011). Seller may choose to accept such demand in order to stay competitive in the region market of the buyer country relatively in far distance (Quast & Locatelli, 1997). Spain and Italy receive Algerian gas, and in respect to the border price, it is much higher for Spain, except for in Northern region, in which Italy's demands are concentrated, the border price is at a rate to those of other countries. In other words, if the distance of transportation is far, it could serve as a factor in lowering the contract price in order to match the final consumer's price to those of other countries. Among pricing formulas, this approach can be observed in formulas that set prices that reflect the market conditions through the Net-back approach. Distance, LNG distance and PNG distance variables were all included to represent costs arising from the transportation distance.

HL gas dummy variable was included to reflect differences in the heating value. In general, high-thermal and low-thermal gas are classified by the place of origin, with Norwegian and Russian gases typically having higher heating value that of Dutch. Costs arising from these differences in the heating value can vary according to supply routes and the characteristics of gas supply infrastructure. Moreover, the gas reserve of a supplier country can be a determinant factor for production expenses, because the amount attainable from the reserve by investing such expenses will determine preserving costs involved in exploration, drilling, development and production. In gas fields with large reserves of gas, production costs can be lowered. In early stages of development, however, when there is not sufficient demand even with large reserves, a particular country may be burdened with production costs in the form of a high price. Proved reserve was included to identify the characteristics of costs arising from the amount of reserves and how they affect pricing.

3.2.4 Demand variables

The characteristics of a gas buyer country can be an indicator that represents the scope and necessity of a gas contract, as gas contract are bilateral agreements between a seller and buyer. Total import is a direct variable that represents a buyer country's quantity of gas imported. In principle, importing large quantities can work favorably in negotiating contract price. Large quantities of import, however, can also underscore the necessity of gas supply contract and can have adverse effects on the contract price. Gas share represents the ratio of gas to the total primary energy supply and pertains to the consumer country's makeup of energy sources. If there is a high dependency on gas compared to other fuel sources, a gas contract may be more essential, and, on the contrary, as in the case of aforementioned total quantity demanded, a structure wherein gas comprises a higher ratio can lower the contract price due to the quantity effect (Knittel, 2003). Generation share represents the ratio of gas generation sector to the final demand. In case of electricity, there is a higher need to satisfy stable and continued demand compared to other energy sources. The fact that the ratio of generation sector that uses gas as fuel is high means there is a need for maintaining gas supply contract and this can serve as an indicator for the necessity of gas supply contract.

Year dummy was included for the purpose of controlling the characteristics per annum or demand levels. In particular, the year 2010 and 2014 marked the period of time where changes in the linked indexes appeared in several European gas contracts. Following the development of spot market in 2010, there was a demand for increasing the ratio of spot-indexed price, and the variable was included for the purpose of identifying the changes in contract price caused by linked index and controlling the influence such changes on other factors.

Table Ⅱ- 2. Variables descriptions

	Variable name		Descriptions	Sources
Market-specific Variables	Seller pw to World	X1	seller's power to world seller's share of supply quantity to world consumption quantity	IEA(2015)
	Seller pw to EU	X2	seller's power to Europe seller's share of supply quantity to European region consumption quantity	IEA(2015)
	Buyer pw to World	X3	buyer's power to world buyer's share of consumption quantity to world consumption quantity	IEA(2015)
	Buyer pw to EU	X4	buyer's power to Europe buyer's share of consumption quantity to European region consumption quantity	IEA(2015)
	Supply ch	X5	Number of competing source	IEA(2015)
	Mkt strc	X6	market structure market share of the largest company in gas industry	OECD(2014)
	Ownership	X7	No ownership=1, predominantly owned by public shareholder (over 50%)	Access website by each cooperate

	State own	X8	State has the ownership on that firm	Access website by each cooperate
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	Depends on route
	Ukr dum	X14	pass through Ukraine or not	Depends on route
	Flex	X15	flexibility of supply quantity 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	
Cost variables	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
Demand Variables	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	

3.3 Method

Purpose of this paper is building up the model to predict the contract price for long-term supply contract and selecting the price determinant factors and figuring out its coefficient to price. The factors determined contract price is considered as having many potential variables of which only a few factors are significant. Furthermore, details of contract is confidential, thus, information about realized factors are not open to access. Under situation such as number of independent variables greater than the sample size, Data with a large number of variables relative to the sample size called “high-dimensional data” (Belloni et al., 2014).

Belloni et al.(2014) pointed out two reasons why high-dimensional data arise. First, the data may be inherently high dimensional in that many different characteristics per observation are available. Second, even when the number of available variables is relatively small, researchers rarely know the exact functional form with which the small number of variables enters the model of interest. Researchers are thus faced with a large set of potential variables formed by different ways of interacting and transforming the underlying variables (Belloni et al.,2014). The latter is the reason why we deal with the high-dimensional data for this paper.

The ordinary least squares estimator will fit the data perfectly with high value of R-square with this high-dimensional data set. However, using the estimated model is likely to result in very poor forecasting properties out-of-sample because the model estimated by least squares is overfit with fitting the noise that is present in the given sample, and is not useful for forming out-of-sample predictions (Belloni et al., 2014). Main idea for designing model having high-dimensional data is "Approximately sparse" regression models. These models are characterized by having many potential predictor/control variables of which only a few are important for predicting the outcome (Belloni et al., 2014). With this assumption, there are the strategies for dimension reduction or regulation (Belloni et al., 2014; Hastie et al., 2001; Chernozhukov et al., 2015).

The well-known techniques for regulation are “least absolute shrinkage and selection operator”, (hereinafter lasso), ridge regression, and subset selection (Belloni et al., 2014; Hastie et al., 2001). lasso and ridge regression are a continuous process that shrinks coefficients, meanwhile, subset selection finds for each $k \in \{01,2,\cdots,p\}$ the subset of size k that gives smallest residual sum of squares(Tibshirani, 1996;Belloni et al., 2014; Hastie et al., 2001; Chernozhukov et al., 2015). These methods tend to do a good job at prediction, which is what they are designed for, but they can often lead to incorrect conclusions when inference about model parameters such as regression coefficients is the object of interest (Belloni et al., 2014;Leeb & Pôtscher 2008). In this paper, we approach prediction model through lasso, and then inference for estimating model parameter via double selection.

3.3.1 Least Absolute Shrinkage and Selection Operator (LASSO)

The most widely applied conventional approach to build a model with many potential predictor/control variables is the researcher making an ad hoc decision through intuitive appeal or start starting by imposing some dimension reduction However, it does leave one wondering whether the correct variables and functional forms were chosen (Belloni et al., 2014). Nonparametric methods, such as traditional series/sieve expansions, can uses a series of transformations of these variables in estimation, however, it is again assumed that the most important terms for predicting are contained within a pre-specified set of transformed variables determined by the researcher that is quite small relative to the number of observation (Belloni et al., 2014).

Lasso was proposed by Tibshirani(1996) as a new technique for prediction accuracy and drawing meaningful conclusion by shrinking some coefficient. Ridge regression shrinks some coefficients with restriction such as L_2 norm($\sum_j \left|\beta_j\right|^2 \leq t$) and avoid overfitting, but it does not set any coefficients to 0 and hence does not give an easily interpretable model. Meanwhile, subset selection provides interpreted model by variable selection, but it can reduce its prediction accuracy. On the other hand, lasso shrinks some coefficient and sets others 0, and hence tries to retain the good features of both subset selection and ridge regression (Tibshirani, 1996).

Suppose that we have data $\left(\mathbf{x}^i, y_i\right)$, $i = 1,2,\cdots,N$ where $\mathbf{x}^i = (x_{i1},\cdots,x_{ip})^T$, are the predictor variables and y_i are the responses. We assume that the x_{ij} are standardized so that $\sum_i x_{ij}/N = 0$, $\sum_i \frac{x_{ij}^2}{N} = 1$. Letting $\widehat{\boldsymbol{\beta}} = (\hat{\beta}_1,\cdots,\hat{\beta}_p)$, the lasso estimate $\left(\hat{\alpha},\widehat{\boldsymbol{\beta}}\right)$ is defined by

$$\left(\hat{\alpha},\widehat{\boldsymbol{\beta}}\right) = argmin\{\textstyle\sum_{i=1}^{p}(y_i - \alpha - \sum_j \beta_j x_{ij})^2\} \text{ s.t. } \sum_j\left|\beta_j\right| \leq t \quad \cdots\cdots\cdots\cdots \text{Eq. (Ⅱ-1)}$$

Here t > 0 is a tuning parameter. We can assume without loss of generality that $\bar{y} = 0$ and hence omit α(Tibshirani, 1996).

Belloni et al. (2014) proposed lasso estimator defined as

$$(\hat{\boldsymbol{\beta}}) = argmin\{\sum_{i=1}^{P}(y_i - \alpha - \sum_j \beta_j x_{ij})^2 + \lambda_t \sum_j |\beta_j| \quad \cdots\cdots \text{Eq. (Ⅱ-2)}$$

where $\lambda > 0$ is the penalty level, which controls the degree of penalization. Let t_0 be the full least squares estimates which means $\lambda = 0$ and let to $t_0 = \sum |\beta_j^0|$. Values of $t < t_0$ will cause shrinkage of the solutions towards 0, and some coefficients may be exactly equal to 0. For example, if $t = t_0/2$, the effect will be roughly similar to finding the best subset of size $p/2$ (Tibshirani, 1996).

The penalty function in the lasso is special in that it has a kink at 0, which results in a sparse estimator with many coefficients set exactly to zero. Thus, the lasso estimator may be used for variable selection by simply selecting the variables with nonzero estimated coefficients (Belloni et al., 2014).

Criteria for t or λ is prediction error. Probably the simplest and most widely used method for estimating prediction error is cross-validation (Hastie et al.,2001). This method directly estimates the expected extra-sample error $\mathrm{Err} = \mathrm{E}[\mathrm{L}\left(\mathrm{Y}, \hat{f}(X)\right)]$, the average generalization error when the method $\hat{f}(X)$is applied to an independent test sample from the joint distribution of X and Y (Hastie et al.,2001). If plenty data set is ready, separate set for testing prediction error is the best. To finesse the problem, we uses part of the available data to fit the model, and a different part to test it. It is called K-fold cross-validation(Hastie et al.,2001). Let $\kappa: \{1, \cdots, \mathrm{N}\} \mapsto \{1, \cdots, K\}$ be an indexing function that indicates the partition to which observation i is allocated by the randomization. Denote by $\hat{f}^{-k}(x)$ the fitted function, computed with the k-th part of the data removed. Then the cross-validation estimate of prediction error is

$$\mathrm{CV}(\hat{f}) = \frac{1}{N}\sum_{i=1}^{N} L(y_i, \hat{f}^{-\kappa(i)}(x_i)) \quad \cdots\cdots \text{Eq. (II-3)}$$

Prediction error varies from tuning parameter λ , thus model selected results in the lowest prediction error with certain λ through lasso.

For running lasso, widely applied algorithm is from LARS(Efron et al. ,2004) and GLMnet(Friedman et al., 2010). The latter is used for our prediction model MATLAB code. With Gaussian data generated, given restriction such as $\frac{(1-\alpha)}{2} \times \sum_j |\beta_j|^2 + \alpha \times \sum_j |\beta_j|$, we get the prediction model via lasso when $\alpha = 1$. With prediction error according to λ through cross-validation, we use cvglmnet(X,Y,'family') for the lowest prediction error and standard error of its estimator.

3.3.2 Double selection

In the case of high-dimensional data, overfitting through ordinary least square can be avoided by lasso with shrinking method. Though prediction accuracy improve problem the nonzero coefficients tend to be substantially biased towards zero(Belloni et al., 2014). An appealing method to alleviate this bias is to employ the Post-LASSO estimator as in Belloni and Chernozhukov (2013) and Belloni, Chen, Chernozhukov, and Hansen (2012). The Post-LASSO estimator works in two steps. First, LASSO is applied to determine which variables can be dropped from the standpoint of prediction. Then, coefficients on the remaining variables are estimated via ordinary least squares regression using only the variables with nonzero first-step estimated coefficients (Belloni & Chernozhukov, 2013) and Belloni, Chen, Chernozhukov & Hansen, 2012). Furthermore, OLS post-Lasso estimator can perform strictly better than Lasso, in the sense of a strictly faster rate of convergence(Belloni & Chernozhukov, 2013).

Suppose a linear model with treatment variable, d_i , is taken as exogenous after conditioning on control variables:

$$y_i = \alpha d_i + x_i' \theta_y + r_{yi} + \zeta_i \quad \cdots\cdots \text{Eq. (II-4)}$$

where $\mathrm{E}\left[\zeta_i | d_i,\ x_i,\ r_{yi}\right] = 0,\ x_i$ is p $-$dimensional vector of controls where $p \gg n$ is allowed, r_{yi} is an approximation error, and the parameter of interest is α, the effect of the treatment on the outcome(Belloni et al. 2014). The exclusion of variable that is highly correlated with to the treatment will lead to substantial omitted-variable bias if the coefficient in θ_y associated with the variable in nonzero (Belloni et al. 2014).

Belloni et al.(2014) intuitively explain the problems to estimate α. If treatment variables, d_i, force control variables, x_i , to be dropped in lasso, OLS, d_i and x_i on y_i, being conducted after lasso, happen to be omitted-variable bias. In other words, In other words, d_i having a relation with x_i such as $d_i = x_i'\theta_d + r_{di} + v_i$ where $\mathrm{E}[v_i \mid x_i, r_{di}] = 0$ make the significant variable amongst x_i be excluded.

To overcome the limitation of post-lasso procedure Cernozhukov and Hansen(2012) and Belloni et al. (2013) proposed "double selection" procedure which will lead to valid inference about a even when selection mistakes are allowed. Using both selection steps also enhances efficiency by finding variables that are strongly predictive of the outcome and may remove residual variance (Cernozhukov & Hanse, 2012) ; Belloni et al., 2013) ; Belloni et al., 2014).

Due to model selection mistakes where important variables are missed post lasso could lead to biased estimates of α. This strong omitted-variables bias is absent from the distribution of the "double selection" estimator, which was specifically designed to reduce the influence of such mistakes as discussed above (Belloni et al., 2014).

In this paper, lasso is conducted to select the variables for prediction accuracy amongst potential predictor/control variables to contract price, and then control variables for each treatment variable are selected through second lasso step. Last, The coefficients of variables of interest is provided as OLS estimator.

4. Results

4.1 LASSO variable selection

When lasso is performed on the 26 variables of European gas contract prices, the coefficient is displayed as the following graph according to λ, which is the constraint magnitude. The closer to zero, the bigger the constraint magnitude (λ≈1 or t≈ 0) which means smaller selective variable, that is, there are many variables with coefficients that are not zero, and the weaker the constraint, many variables can be observed to have coefficients other than zero.

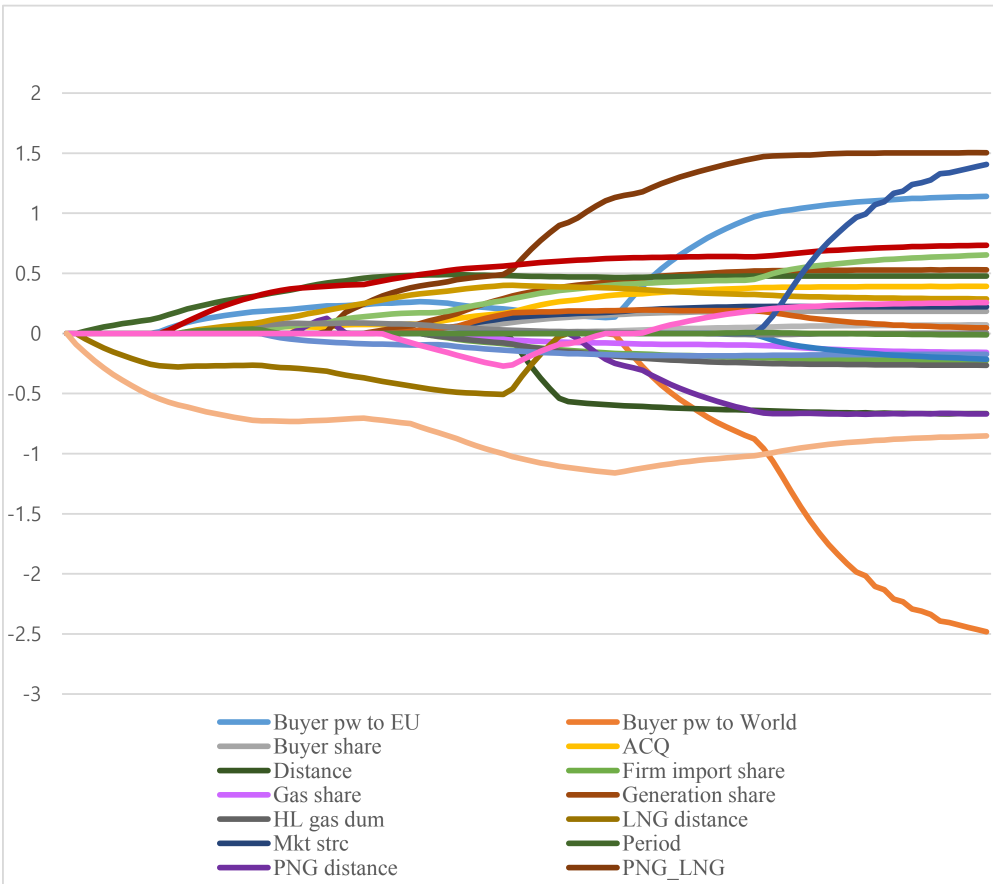


Figure Ⅱ- 1. Lasso estimator

Some fluctuations appear whenever lasso is performed due to the prediction errors caused by cross validation which are based on estimated data. For this reason, after a hundred lasso performances, the group of variables selected under the constraint condition of average value of λ(approximately 0.045) that showed the least prediction error, was finally chosen.

The chosen variables are 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 and Year Dum (YEAR), a total of 11 variables. This illuminates the prediction model for European gas contract prices as below. The value of the variable, as mentioned, is the data that has been converted to average of 0 and standard deviation of 1.

$$y_i = 0.215BPE_i + 0.054ACQ_i - 0.299LD_i + 0.392PD_i + 0.383OWN_i - 0.060SS_i + 0.075SPE_i + 0.083SC_i + 0.163FLEX_i - 0.728YEAR_i \quad \cdots\cdots\cdots \text{Eq. (Ⅱ-5)}$$

In the group of variables that minimizes prediction error of the first lasso performance, Seller pw to Europe and Buyer pw to EU that represent market structure are included, which signifies that the bargaining power of supplier and consumer has an influence over contract price in the region market. The influence of a consumer country’s market structure, such as the Ownership, over contract price prediction also proved to be a meaningful variable. The existence of transaction costs inherent in the characteristics of gas supply also influenced the agreement price and by choosing variables that include Seller share, ACQ, Period and Flex various forms of transaction costs were observed. The influence of LNG distance on contact price, in respect to transportation costs, was also confirmed. Year dum, which can act as an indicator of the characteristics of fluctuations in linked index also wielded influence over contract price. This model was used to predict contract price of gas by not only identifying the factors traditionally thought to have influences from previous studies, but by uncovering various potential factors that could arise from the characteristics of gas supply contracts, and therefore could offer guidelines for parties about to enter into new contracts.

4.2 Double selection

For the second phase, lasso is performed on each of the 11 variables in order to conduct double selection, during which variables that are similarly significant to the interested variable and thus show high inter-variable correlation, and those that can potentially interrupt alleviating endogeneity during final regression analysis are excluded. When lasso is performed, for instance, to find additional controlled variable in respect to Buyer pw to EU, if Buyer pw to World is included, then Buyer pw to World tends to explain most of the values pertaining to Buyer pw to EU, and therefore other variables that could potentially alleviate the problem of endogeneity end up not being chosen during regression analysis. In this regard, in the second phase of lasso performance with an aim to find the controlled variable in order to accurately estimate the coefficient of Buyer pw to EU, Buyer pw to World was excluded so that the variable that can alleviate the problem of endogeneity could be chosen. Essentially, variables that display high correlation coefficients were excluded, although the variables that displayed meaningful correlation even at 0.1% of the correlation level were also excluded, albeit having displayed low correlation coefficient value(see

Appendix 1) . Accordingly, the variables outlined in the Table Ⅱ-3 below were excluded from analysis in the second phase of lasso performance. As the results of the second phase, the controlled variables to be added to each variable are outlined in the Table Ⅱ-4 below.

Table Ⅱ- 3. 2nd LASSO step

Dependent variable with LASSO	Excluded variable
Buyer pw to EU	Buyer pw to world , Total import
ACQ	Firm import share
LNG distance	Distance, PNG distance, PNG_LNG
Period	
PNG distance	ACQ, Distance, LNG distance, PNG_LNG, Transit num, UKR dum
Ownership	
Seller share	
Seller pw to EU	Seller pw to world, Proved reserve
Supplych	
Flex	HL gas dum
Year dum	

Table Ⅱ- 4. Selected variables to control

Variables of interest	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
Supply ch	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

4.3 Regression results

Additional controlled variable was chosen through double selection of the 11 variables that were included as part of the prediction model derived from the results of the first phase lasso, and regression analysis was conducted on those 11 variables.

Xi, in the first row of the Table Ⅱ-5 and Ⅱ-6, was the selected variable from the 1st lasso phase, and double selected in the 2nd lasso phase to estimate the coefficient of that variable by conducting regression analysis that included such double selected variable as the controlled variable. In respect to market structure, Seller pw to EU (X2) and Ownership (X7), were significant, while in terms of transaction costs, Period and Flex were significant and finally, for costs LNG Distance was significant. The results were similar for Log Specification, and PNG Distance was added as a significant variable.

Table Ⅱ- 5. Regression results with double selected variables (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	0.0654**	0.0445	0.0828	0.0375**	0.1075	0.1063	0.0252	0.0300*	0.1171	0.1098	0.0386
	(0.029)	(0.033)	(0.159)	(0.018)	(0.164)	(0.161)	(0.020)	(0.016)	(0.171)	(0.173)	(0.024)
buyerpwtoeu	-0.0056	0.0095	0.0476	0.0497	0.1202	0.3281	0.2343	0.045	0.1982	0.1144	0.0478
	(0.058)	(0.064)	(0.056)	(0.034)	(0.362)	(0.383)	(0.373)	(0.050)	(0.408)	(0.396)	(0.060)
supplych	0.036	0.0356	0.0264	0.0776	0.029	0.0023	0.074	0.037	0.051	0.0555	0.0196
	(0.062)	(0.059)	(0.064)	(0.050)	(0.063)	(0.064)	(0.049)	(0.053)	(0.063)	(0.062)	(0.060)
ownership	1.0347***	1.0248***	0.8821**	0.8473**	0.7405*	0.8038**	0.7355***	0.5927**	0.8748**	0.8064*	0.7946**
	(0.372)	(0.343)	(0.330)	(0.337)	(0.385)	(0.387)	(0.247)	(0.248)	(0.379)	(0.405)	(0.334)
seller_share	-0.0251	-0.0184	-0.0158	-0.0159*	-0.0206	-0.0075	-0.0142	-0.0119	-0.0185	-0.0179	-0.0149
	(0.016)	(0.015)	(0.011)	(0.009)	(0.017)	(0.012)	(0.009)	(0.009)	(0.012)	(0.016)	(0.013)
ACQ	0.1443	0.1575*	0.1094	0.0776*	0.1011	0.0404	0.0572	0.0877	0.1342	0.1168	0.089
	(0.087)	(0.087)	(0.087)	(0.042)	(0.080)	(0.048)	(0.039)	(0.070)	(0.088)	(0.085)	(0.075)
period	0.0799**	0.0865***	0.0888***	0.0862***	0.1110***	0.1018***	0.0976***	0.1099***	0.1008***	0.0920***	0.0795***
	(0.030)	(0.030)	(0.029)	(0.028)	(0.031)	(0.031)	(0.028)	(0.027)	(0.032)	(0.032)	(0.028)

flex	0.1771	0.1214	0.4211	0.1621	0.4946	0.2564	0.2716	0.5980*	0.0509	0.1097	0.4337
	(0.397)	(0.418)	(0.372)	(0.374)	(0.467)	(0.466)	(0.326)	(0.342)	(0.469)	(0.468)	(0.343)
LNG_distance	0.0006	0.0008*	-0.0001**	-0.0001**	-0.0002***	-0.0002**	0.0003	-0.0002***	-0.0002*	-0.0001	-0.0001*
	(0.001)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PNG_distance			-0.0005	-0.0005	-0.0003	-0.0004		-0.0002	-0.0007	-0.0005	-0.0004
			(0.001)	0.000	0.000	(0.001)		0.000	(0.001)	0.000	0.000
year_dum	-1.7291***	-1.4403***	-1.4358**	-1.0876***	-0.7138	-1.1636*	-0.8282	-0.9372***	-0.698	-0.8317	-1.8487***
	(0.474)	(0.355)	(0.616)	(0.270)	(0.606)	(0.651)	(0.569)	(0.255)	(0.703)	(0.637)	(0.488)
buyer_share	0.0222	0.0093			0.0132					0.0034	0.0117
	(0.020)	(0.021)			(0.022)					(0.023)	(0.019)
distance	-0.0008	-0.0010*					-0.0004				
	(0.001)	(0.001)					0.000				
firm import share	-0.0356	-0.0393	-0.0284		-0.0282			-0.0253	-0.0324	-0.0248	-0.0212
	(0.039)	(0.039)	(0.040)		(0.037)			(0.035)	(0.041)	(0.039)	(0.036)
gas share	-0.364			0.2994	1.4972				1.4516	0.727	-3.1107
	(2.205)			(1.667)	(2.025)				(2.257)	(2.401)	(2.477)
generation share	0.0576	0.0311	0.0435			0.0606*					0.0787*
	(0.036)	(0.022)	(0.032)			(0.035)					(0.041)
HL gas_dum	-0.5447	-0.5481		-0.357	-0.2681	-0.37			-0.5208	-0.4537	

	(0.445)	(0.443)		(0.426)	(0.462)	(0.460)			(0.475)	(0.475)	
mkt strc	0.2319		0.2078	-0.019		0.2556				-0.0086	0.3342
	(0.226)		(0.229)	(0.144)		(0.241)				(0.160)	(0.230)
transit num	-0.1228		-0.1287		-0.0288	0.007			-0.1403		
	(0.264)		(0.236)		(0.265)	(0.252)			(0.258)		
UKR dum	0.7628	1.1125	0.6268			0.204			0.8896		
	(1.183)	(1.151)	(1.196)			(1.113)			(1.210)		
proved reserve		0.0131			0.0017	0.0207	0.0102		0.0198	0.0125	
		(0.029)			(0.028)	(0.027)	(0.022)		(0.029)	(0.032)	
stateown		-0.015	0.3167			0.2954		0.0807	-0.1699	-0.0394	0.6685
		(0.474)	(0.463)			(0.558)		(0.389)	(0.602)	(0.610)	(0.585)
sellerpwtoworld			-0.111		-0.1448	-0.1781			-0.1918	-0.1794	
			(0.367)		(0.388)	(0.370)			(0.393)	(0.409)	
PNG_LNG					1.3087*	1.1032		1.2199**			
					(0.679)	(0.689)		(0.576)			
total import					-0.0217	-0.0539				-0.0204	
					(0.080)	(0.084)				(0.087)	
buyerpwtoworld							-0.3794		-0.3874		
							(0.819)		(0.897)		

_cons	6.9695***	7.7099***	6.5040***	7.2517***	6.6022***	5.4308***	6.8014***	6.8823***	7.5644***	7.6251***	6.3306***
	(1.382)	(1.168)	(1.344)	(0.930)	(1.329)	(1.218)	(0.767)	(1.026)	(1.271)	(1.426)	(1.270)
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

Table Ⅱ- 6. Regression results with double selected variables (Log-linear specification)

	Selected variables by LASSO / Log-linear Specification										
	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se
ln_sellerpwtoeu	-0.0465	-0.038	0.0600**	0.0678**		0.0288	0.0197	0.0600**	0.0233		-0.0338
	(0.139)	(0.129)	(0.026)	(0.025)		(0.028)	(0.025)	(0.024)	(0.027)		(0.139)
ln_buyerpwtoeu	-0.1381	0.1681	0.5148	0.0335	0.5038	0.0722		-0.0444	0.0501	0.1473	0.454
	(0.494)	(0.590)	(0.635)	(0.039)	(0.474)	(0.595)		(0.522)	(0.619)	(0.610)	(0.652)
ln_supplych	0.0761*	0.0576*	0.0445	0.0752*	0.0482	0.042	0.0625*	0.0532	0.0506	0.054	0.0566
	(0.041)	(0.034)	(0.044)	(0.038)	(0.039)	(0.040)	(0.032)	(0.036)	(0.039)	(0.038)	(0.041)
ownership	0.1037**	0.0768*	0.0663	0.0764*	0.0533	0.0729	0.0595**	0.0628	0.0729	0.0781*	0.053
	(0.048)	(0.042)	(0.055)	(0.040)	(0.044)	(0.050)	(0.027)	(0.041)	(0.050)	(0.043)	(0.046)
ln_seller_share	0.1016	0.0659	-0.0051	-0.0061	0.0697	-0.0015	-0.0004	0.0018	-0.0031	0.044	0.0858

	(0.133)	(0.126)	(0.012)	(0.011)	(0.124)	(0.012)	(0.011)	(0.011)	(0.011)	(0.124)	(0.134)
ln_ACQ	0.3076	-0.0331	-0.4118	0.0520*		0.0359	0.0283	0.1374	0.0034		-0.2519
	(0.483)	(0.534)	(0.637)	(0.027)		(0.029)	(0.023)	(0.519)	(0.622)		(0.608)
ln_period	0.032	0.0343*	0.0391*	0.0361*	0.0363*	0.0354	0.0391**	0.0538**	0.0387*	0.0339*	0.0377*
	(0.022)	(0.020)	(0.022)	(0.021)	(0.021)	(0.021)	(0.019)	(0.020)	(0.020)	(0.019)	(0.021)
flex	0.0391	0.0137	0.0269	-0.0136	0.0083	-0.004	0.0544	0.0426	-0.0089	0.0011	0.0262
	(0.053)	(0.049)	(0.042)	(0.046)	(0.046)	(0.046)	(0.037)	(0.040)	(0.043)	(0.043)	(0.040)
LNG_distance	-0.0000***	-0.0001***	-0.0000**	-0.0000***	-0.0000***	-0.0000***	-0.0000***	-0.0000***	-0.0000***	-0.0000***	-0.0000**
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PNG_distance	-0.0001**	-0.0002***	-0.0001	-0.0000*	-0.0001***	-0.0001**	-0.0001***	0	-0.0001***	-0.0001***	-0.0000*
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
year_dum	-0.2122***	-0.1683**	-0.1295*	-0.1534***	-0.1011*	-0.1838**	-0.1480***	-0.1419**	-0.1577**	-0.1494**	-0.1437*
	(0.061)	(0.065)	(0.074)	(0.031)	(0.059)	(0.069)	(0.027)	(0.063)	(0.070)	(0.072)	(0.073)
ln_buyer_share	-0.0998	-0.0683			-0.0765					-0.051	-0.0952
	(0.138)	(0.130)			(0.129)					(0.129)	(0.140)
ln_distance	0.0883**	0.0392					0.0484				
	(0.043)	(0.048)					(0.036)				
ln_firm import share	-0.2615	0.0778	0.4646		0.0445*			-0.1007	0.0266	0.0287	0.3116
	(0.482)	(0.548)	(0.644)		(0.026)			(0.529)	(0.629)	(0.030)	(0.616)

ln_gas share	-0.0454			-0.0018	0.0487				0.0709	0.0731	-0.085
	(0.084)			(0.055)	(0.065)				(0.066)	(0.071)	(0.084)
ln_generation share	0.0554*	0.0392	0.0411			0.0471*					0.0580*
	(0.032)	(0.023)	(0.030)			(0.027)					(0.033)
HL gas_dum	-0.021	-0.067		-0.0592	-0.0787	-0.0833*			-0.0868*	-0.0849*	
	(0.052)	(0.049)		(0.049)	(0.049)	(0.048)			(0.046)	(0.046)	
ln_mkt strc	0.0118		0.0142	0.0032		0.0111				0.0077	0.0131
	(0.014)		(0.014)	(0.012)		(0.013)				(0.012)	(0.014)
ln_transit num	-0.0091		-0.0014		0.005	0.0057			0.0042		
	(0.020)		(0.021)		(0.019)	(0.020)			(0.018)		
UKR dum	0.0938	0.1432	0.0441			0.1141			0.1296		
	(0.134)	(0.117)	(0.133)			(0.122)			(0.121)		
ln_proved reserve		0.0644**			0.0593**	0.0772***	0.0450**		0.0870***	0.0812***	
		(0.029)			(0.024)	(0.027)	(0.020)		(0.025)	(0.025)	
stateown		-0.0273	0.0767			-0.0638		0.001	-0.1041	-0.0908	0.0928
		(0.103)	(0.084)			(0.090)		(0.080)	(0.089)	(0.090)	(0.082)
ln_sellerpwtoworld					-0.042					-0.029	
					(0.128)					(0.128)	
PNG_LNG					0.0452	0.0101		0.1496*			

					(0.090)	(0.092)		(0.075)			
ln_total import					-0.3669	-0.0447				-0.0574	
					(0.469)	(0.603)				(0.566)	
ln_buyerpwtoworld							0.0336				
							(0.036)				
_cons	1.9366	1.4268	0.2205	1.8313***	2.2466**	2.0072**	1.8086***	2.0206	2.1001	2.0410*	0.5232
	(1.369)	(1.870)	(1.997)	(0.165)	(1.071)	(0.918)	(0.309)	(1.652)	(1.897)	(1.012)	(1.863)
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

Seller pw to EU represent ratio of a supplier country's market share in European region market, and it was illustrated that for every 1%P increase, contract price tended to increase by 0.065$/mmbtu. This means if the ratio of the quantity supplied by a certain supplier country is high, it can have an upper hand in its bargaining power. The undergoing process of Europe seeking other sources of supply in an effort to reduce dependency on Russian gas, could be viewed as a strategic move to disentangle itself from such supplier dominant market structure, and this move could also be a measure of lowering the price levels in approaching gas contracts in Europe.

The corporate structure of a consumer country showed significant coefficient in terms of contract price. In instances when there was ownership as opposed to none, the contract price increased by 0.85$/mmbtu. For log specification, price changes were significant, nearing 8% of increase. This illustrates that for a consumer country's firm with ownership can have a comparative advantage in negotiating contract price as opposed to a firm without ownership. In cases where the firm is a public operator, it displayed a lack of accountability regarding high fuel prices that are considered as costs, or at least as far as corporations are concerned, whereas with firms that have ownership, there is an incentive to lower fuel purchasing costs by lowering contract price.

In terms of transaction costs, Period, which represent passage of time since entering into contract, proved significant. When such long-term contract passed 1 year, the contract price increased by 0.1$/mmbtu. For log specification, the contract price increased by 0.04% when the number of year passed increased by 1%. This suggests that as with the passage of time from entering into contract, or to put it differently the remainder period of the contract is shortened, a buyer has less of an incentive to demand for a price adjustment. Price adjustment practices in recent Europe have been requested by buyer during renewal of contract, setting demands for a renewed contract price and requesting price adjustments from seller give rise to transaction costs in cases of long-term contracts. This could be attributable to decreasing incentives for price adjustments with the passage of time.

Flexibility is a variable that represents costs derived from adjusting quantity supplied in long-term gas trade, and when the agreement was set out to increase the flexibility of quantity, it brought about 0.6$/mmbtu increase in contract price, as compared to the instance when it was not. This confirms the general understanding that increasing the flexibility of quantity supplied will drive up gas prices. It can be viewed that a long-term gas supply contract itself, moreover, means stable and secure source of profit for a supplier, and flexibility of quantity supplied undermines such stability, thereby incurring penalties. In other words, significant flexibility variable represents the existence of transaction costs.

In terms of costs, LNG distance showed significant results. When the transportation distance of LNG increased by 1km, the price decreased by 0.0002$/mmbtu. Generally speaking, if the transportation distance is far, the transportation costs will rise and subsequent increase in importing price cannot be avoided, and this ironically presents buyer with leverage. The fact that there were cases where the price of gas that had reached its final place of consumption did not differ from other regions or countries, signifies there is a room for negotiating preservation of loss arising from transportation costs. This result was also displayed in log specification, which showed 0.005% drop of contract price when the distance rose by 1km. PNG distance showed results that were similar to those of log specification as well, with 0.01% decrease in price with 1km increase. This provides support for the potential of PNG to drive down the contract price as the distance passed through pipeline is increased.

Year dum showed 1.8$/mmbtu spike up (about 15%p increase in log specification) in price in the year 2014, compared to that of the year 2010. At the same period crue oil price and gas hub price increase 3.59 $/mmbtu (brent oil) and 1.69$/mmbtu respectively. It could be assumed that with the increase in oil and gas prices, contract price has not been reflected that much of oil price increase. Hub-pricing is accountable for the changes in linked index, therefore, it could also be suggested that such changes make contract price partly decrease, compare to that of 100% oil-indexing.

5. Discussion

5.1 Long-term contract and gas price

It is difficult for a liberal market structure to emerge in gas market. This difficulty stems from the characteristics of “gas” that sets it apart from other commodities. The sources of supply for gas are limited to certain countries with gas reserves, and for those countries fortunate enough to have such resource gas has served as a major source of national income and political power in international affairs. Countries that possess the resource against the backdrop of the state of current affairs in which fossil fuels are dwindling, are induced to strategically manage the production and export of such resource and the commodity is not fully governed by the principle of supply and demand. Consequently, the gas market is a domain where the work of the "invisible hand" is fairly limited. The development of gas fields and production, moreover, require investments of great magnitude, hence the prevalence of bilateral long-term agreements. As is the reality for gas sales and purchase agreements to be mostly, if not all, bilateral agreements based on negotiations, it is not feasible for gas to be traded in a free market where commodities can freely enter or exit. It is quintessential to have a robust system and ubiquitous infrastructure for free market to flourish against the national interest of each country, and it is no easy task to bring about transitions in market structure against the national interest of each sovereign state.

This study was motivated to find price determining factor in bilateral long-term gas supply contracts that display such different characteristics from other commodities by focusing on bargaining power, and further aimed to identify the source of such bargaining power. European market, in particular, displays a high ratio of gas, large scale of imports and high ratio of a certain countries' market share to the total imports. Trends throughout history in such a market have attested to the supplier-dominant contracts. Suppliers may display behaviors to maintain dominance by decreasing quantity produced in the short-term, or in the long-term, hindering development of new gas fields. There is a cause for concern with such behaviors of suppliers, for they could invoke energy supply crisis and subsequent adverse effects to national economy, comparable to many instances of OPEC controlling oil production that the global community has helplessly witnessed over the years. This study examined the conditions that supplier and consumer countries faced in such supplier-dominant negotiations, and how bargaining power influenced contract price.

The existence of transaction costs derived from the characteristics of gas trade presents the problem of sharing the burden of such costs, and gives rise to the opportunity for bargaining power to come into effect. The burden of commercial risks involved in gas supply is very unfavorable to consumers (KEEI, 2005), for TOP provision or transaction costs arising from adjustments in renewal agreements are almost entirely levied on buyers. Supplier-dominant environment can also be observed in burden of such transaction costs, that is sharing of commercial risks.

5.2 Market structure and bargaining power

In respect to bargaining power, the state of a consumer country's market structure is a pivotal factor. It was purported that existing large national gas firms in Europe saw changes in scope of business, ownership structure and firm size because of regulatory reforms that were enacted in an attempt to establish a free gas market, and the bargaining power of European countries that underwent such drastic structural changes during negotiations with suppliers (especially Russia) was significantly weakened (Finon and Locatelli, 2008). In particular, Germany, despite the violation of national antitrust authority, allowed for an energy giant in order to level the playing field of its negotiation with Gazprom in terms of bargaining power, and subsequently reached the agreement for construction of Nord Stream. Liberalized market, on the other hand, put pressure on incumbent firm to negotiate for lower contract price of the long term contract going through less competitiveness in price.

To put it differently, the influence that the status of a consumer country's firm, as manifested in national structure of respective consumer country, wields over negotiations must be considered. It is important to understand 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.

5.3 Geopolitics of bargaining power

The supply and demand of natural resources, as mentioned, differ from that of basic commodities. One of the most fundamental difference is that the accessibility of the resource is dependent on its geographical location. Thus, resource circumstance of a particular country is heavily dependent on its location. If possession of resource is attributable to its geographical factor, then the dominance of a supplier country is due to its geopolitical factor (Bilgin, 2009). The location of a consumer country determines the location of the source of accessible resource, the existence of alternative sources, transportation methods and means. In case of Germany, it does not receive gas in the form of LNG and it only imports in PNG form, and relies much of its import ratio on a handful of supply sources, due to its geographical location. In other words, it is not favorably disposed to receive LNG from LNG supplier countries in North Africa and its proximity to

Eastern Europe dictates that its high dependency on Russian resources.

PNG, in particular, is more affected by geographical factors because of the nature of its infrastructure, with geographical locations of supplier and consumer countries determining transit countries, and the subsequent bargaining power of transit countries is also derived from geopolitical factors (Victor et al., 2006). The source of dominant bargaining power of Ukraine and Belarus has been identified to have stemmed from their respective location (Hubert & Ikonnikova, 2012). Factors that are assumed to have influence over bargaining power of supplier and consumer countries during negotiations inherently have geopolitical characteristics. There is little to no room for a consumer country to change factors arising from geography for they are by definition permanent. For this reason, it may be possible to form a buyer's market in a short-term but hard to maintain in a long-term.

Nonetheless, changes in geopolitical conditions could also bring about changes in market power. Development of the North Pole and sea routes would allow Europe's access to the Arctic's resources and could change power dynamics of North America's influence in Europe. These geopolitical changes could completely transform the supply circumstance of not only Europe, but also Asia. Participation in the development of the Arctic's resources or access to the resources in the North Sea would expand the scope of regions market, and could transform the energy market between Europe and Asia, which, for the time being, is almost non-existent. Simply put, changes in geopolitical conditions will effect changes in national prestige of each country, and here in lies the opportunity to shift the bargaining power in energy negotiations.

Essay III.

Restructuring and Reliability in the electricity industry

1. Introduction

Supply reliability reflects the ability to meet demand and safeguard supply in an electricity system (Energy Research Center of the Netherlands (Sheepers et al., 2007). As energy security becomes a trending issue, the discussion of reliable electricity supplies and essential energy sources also has expanded. Because it is a life-sustaining energy source and an essential prerequisite in utilizing goods and services, electricity tops the agendas of policymakers worldwide, and reliable supply is considered a core objective in the utility industry (Abel et al., 2013). Serious consequences, including damage to national economies from disruptions in the supply of essential energy sources, were witnessed in the California power crisis of 2001 and the blackout of 2003 in the U.S. Northeast. As a result, efficiency and low price are not the only an important issues related to the electricity supply; the electricity industry must address reliability of supply as well.

Concerned voices have been raised about electricity industry restructuring (i.e., liberalization) designed to improve supply efficiency, but which may deteriorate electricity supply reliability (Botterud and Doorman, 2008; Joskow, 2006; Krugman, 2004. That is, trade-offs between efficiency and reliability of supply characterize the electricity industry. The California power crisis of 2001, for example, showed the way deregulation designed to enhance competitiveness not only failed to achieve desired objectives but also resulted in a price hike and subsequent disruption in electricity supplies (Krugman, 2004).

An empirical analysis on the relationship between restructuring and satisfying steady supply of electricity is needed to address industry trade-offs. In this paper, we used an econometric model to evaluate empirically the supply reliability in four separate sub-sectors of the electricity industry.

Supply reliability is realized when electricity continuously meets timely demands and disruption in supply is avoided. An interruption in energy supply might occur at any level of the supply chain; therefore, electricity supply reliability should be evaluated at multiple places in the value chain (Sheepers et al., 2007). For this paper, we divided the electricity supply system, which ranges from acquisition of resources for electricity generation to delivery of energy to customers, into four sub-sectors according to its supply chain: resources, generation, transmission and distribution (T&D), and electricity import. Supply reliability for each sub-sector is measured with the following variables (sub-sector): resource import dependency (resources), reserve factor (generation), disturbance time in T&D (T&D), and electricity import dependency (electricity import). Data from 1987 to 2013 of 15 Organisation of Economic Co-operation and Development (OECD) countries were used to measure restructuring in three dimensions: entry liberalization, privatization, and vertical divestiture.

Although a few studies have addressed electricity supply reliability in the face of industry restructuring, to our knowledge, we present the first empirical study to consider possible dimensions of restructuring and supply reliability. Some previous empirical studies include those from Gugler et al. (2013) and Nardi (2012). However, Nardi (2012) only focused on the effect of “ownership unbundling (vertical divestiture)” on T&D investment and reliability. Gugler et al. (2013) analyzed impacts of liberalization on overall investments in the electricity industry. Of course, the investment variable is closely related to supply reliability; however, as a variable, it is limited in the ability to provide consistent measures. For example, a decrease in investment does not necessarily negatively affect the industry because the monies may come from excess funding. In contrast, the reserve factor as a means to determine generation or disturbance time in T&D directly and consistently measures supply reliabilities.

The paper is organized as follows: Section 2 represents theoretical backgrounds on the relationship between restructuring and supply reliability in the electricity industry. Section 3 explains the econometric model used to investigate the causal relationships between restructuring and reliability. Section 4 shows the results of the regression. Section 5 wraps up this paper with conclusions and recommendations.

2. Studies on restructuring and supply reliability

Some previous literature pointed out disincentives to invest in securing the generation capacity required to meet power demands in a competitive electricity market. In most competitive electricity markets, wholesale prices do not rise high enough to reflect the value of lost load and clear the market. As a result, low prices may lead to underinvestment in generation capacity (Joskow, 2006, 2008; Joskow and Tirole, 2007).[1] Also, underinvestment may be caused by the high risk of lumpy investments in electricity generation, which result from price variability experienced after entry liberalization (Botterud and Doorman, 2008).

U.S. power systems have shown decreasing reserve margins due to underinvestment after entry liberalization and price deregulation (Botterud and Doorman, 2008; Joskow, 2006, 2008). Forward capacity obligations and associated auction mechanisms that determine capacity prices (i.e., capacity payments) are suggested to restore appropriate wholesale market prices and associated investment incentives in the competitive electricity market (Joskow, 2006, 2008; Joskow and Tirole, 2007).

In conclusion, some previous arguments point to the potential negative impacts of entry liberalization on supply reliability. However, because some countries in the competitive market have used mechanisms (such as forward capacity obligations and capacity payments) to make up for the negative impacts (Joskow, 2006, 2008; Joskow and Tirole, 2007), we cannot reach a conclusion without an empirical analysis to reveal evidence of the effects of electricity industry restructuring.

Recently, Gugler et al. (2013) showed empirical results for a similar issue: Entry

1 Several reasons for investment shortfalls in competitive markets are addressed in previous studies: price-insensitive consumers; social costs caused by network collapse or voltage reductions that are not reflected in market prices; price caps, far below the value of lost load, for electricity imposed by regulators to deal with potential market power problems; and pressure to impose marginal cost pricing in a competitive market (Joskow, 2008; Joskow and Tirole, 2007).

liberalization increases investment in the electricity industry. However, they did not address the effect of liberalization, which may be associated with investment shortfalls that lead to failure to meet increasing demand.

The literature on transaction cost economies and economies of vertical integration provides some rationale for the vertical structure of an electricity value chain (Kim et al., 2012). Considering transaction cost theories, we expect to find a potential mismatch in operation and investment (i.e., a coordination problem) between vertically separated firms. The investment and operation contract between separate firms on the vertical value chain will be costly when new investment in one stage requires adjustment in preceding or subsequent stages to realize the potential value of the investment (Armour and Teece, 1980; Kim et al., 2012). Transaction costs increase with increasing relationship-specific investments (Kwoka, 2002; Nardi, 2012); therefore, the coordination of investment plans is particularly useful in an electricity system in which the technology of the generation sub-sector has a close relationship with that used in the T&D sub-sector (i.e., economies of coordination are used) (Michaels, 2006; Nardi, 2012). Buehler et al. (2004) claimed that vertical divestiture reduces investment because firms have poor incentives to invest in networks to gain additional profit. Gugler et al. (2013) emphasized that the electricity industry depends on coordination because demand must equal supply at each point in time, and coordination between infrastructure investments and generation assets may fail if the decision-making entities operate differently from each other or if the market is not regulated.

Gugler et al. (2013) empirically showed that vertical divestiture decreases the investment toward generating capacity and T&D networks for 16 European countries from 1998 to 2008. Nardi (2012) presented the first empirical study to examine the impact of unbundling on T&D supply reliability (network quality) by focusing on 14 Union of the Coordination of the Transmission of Electricity (UCTE) countries between 2001 and 2010. The study showed that network reliability decreases due to delivery delays related to the network disturbance caused by vertical divestiture.

Other previous studies regarding unbundling and incentives to invest deserve recognition for their role in understanding the electricity industry. Contrary to those pointing to the negative effects of vertical divestiture, some economists suggested that vertical divestiture of the transmission network and interconnections presents a structural solution to the problem of low investments in the grid that subsequently results in a high concentration of markets that favor incumbents (Nardi, 2012). There is the lack of incentive for vertically integrated generators to invest in T&D capacity (Borenstein, 2000; Léautier, 2001). Vertically integrated utility companies may recognize that the substitution and strategic effects due to increased T&D capacity would limit their market power in the wholesale electricity markets, and thus, they may strategically underinvest (Nardi, 2012).

The theoretical argument on the effects of privatization on investment applies to supply reliability and underinvestment. The ownership structure of firms in the electricity sector may affect investments in two areas: efficiency and incentive or objective effects (Gugler et al., 2013). If public ownership is related to X-inefficiency, state-controlled energy sectors should receive lower investments than other sectors; however, according to Gugler et al.

(2013), if state-controlled firms have different objectives from private firms, such as the buildup of a good and secure infrastructure for electricity, then the state-controlled firms may invest more than privately controlled firms focused on short-run performance as informed by the tough monitoring of the capital market, stock market myopia, and take-over threats. Based on their empirical estimates for European electricity markets, they showed that public ownership is detrimental to investment.

The security problem may affect resources sectors of the electricity industry. Loss of welfare may result because of price fluctuations, sudden price hikes, or supply interruptions of fossil fuels in international markets, which are caused by resource market concentration and political instability of the resource exporting countries (Jansen & Seebregts, 2010; Lefèvre, 2010; Löschel et al., 2010). In this paper, we chose to use import dependency to measure supply reliability in the resources sector. High resource import dependency increases the risk of supply disruption because price risk and physical availability cannot be controlled (Lefèvre, 2010).

To our knowledge, no previous theoretical or empirical study has been undertaken on the restructuring of the electricity industry and resource import dependency. However, from previous arguments on energy security, we investigate a possible theoretical linkage between restructuring and resource import dependency. Because of the big gap between social and private benefits from enhanced security (externality of the security), long-term and centralized regulation of the industry must be undertaken by the government. Specifically, because decentralized power and private ownership maximize short-run profits during electricity restructuring, security may suffer such that responsible governance is required (Palm, 2008).

Of course, electricity imports alleviate some of the energy supply reliability problem, and limited electricity import dependency can be considered as flexible way to improve response to demand changes in an internationally integrated electricity market. Although flexible electricity imports may improve supply reliability, excessive import dependency can create supply disruptions, as well as price increases and fluctuations caused by external factors. In summary, effects of electricity imports on supply reliability differ by the amount of electricity imported.

In theory, we look at two opposing perspectives. First, new entrants inspired by regulatory reforms, such as through entry liberalization, may have incentives to rely on electricity imports from foreign countries and are not compelled to build up new generating capacity. Second, firms separated by vertical divestiture may prefer to contract with domestic firms than face the higher transaction costs required to deal with foreign suppliers. Such a choice results in decreased electricity imports after restructuring and diminishes the flexibility associated with foreign energy as a supplemental source of electricity.

3. Model

3.1 Variables

Before assessing the effect of restructuring of the power sector on supply reliability, we must first understand the nature of supply reliability and regulatory reforms. To make this assessment for each of the sub-sectors of electricity supply structures (resources, generation, T&D, electricity import), an indicator suitable for quantitatively evaluating supply reliability was selected and measured. Resource import dependency, reserve factor, disturbance time in T&D, and electricity import are used as independent valuables for representing the level of supply reliability in the sub-sectors of resources, generation, T&D, and imports, respectively.

Indicators for quantitatively evaluating electricity industry restructuring were also selected. Electricity industry restructuring is measured in various dimensions—entry liberalization, privatization, and vertical divestiture—as each is used to assess restructuring issues. Despite a few studies that explained the theory of industry restructuring and supply reliability, this is the first empirical study to consider all possible dimensions of regulatory reforms and energy security.

3.1.1 Reliability variables for sub-sectors

For each sub-sector of electricity supply structures—from acquiring resources for power generation to delivery of energy to customers—impediments in supply reliability may differ. According to the peculiarities of each sub-sector, we selected a quantitative index that embraces the uniqueness of each. We divided the process into the sub-sectors of resources, generation, T&D, and electricity import.

3.1.1.1 Resources

Failure in supply reliability indicates the degree of possible interruption in energy supply, and in the resources sub-sector, it suggests inability to procure resources. Such failure is due to a price spike following a sudden price fluctuation or physical unavailability of resources (Lefèvre, 2010). In this paper, we show the level of import dependency in resource procurement as the measurement of possible disruption in resource supply. Eq. (Ⅲ-1) was used to compute the resource import dependency that is used to evaluate supply reliability in the resources sub-sector. It shows the share of net imports of each fossil fuel f in the total primary fossil-fuel energy supply of a particular country i in year t. The equation shows the primary energy supply of each fossil fuel (coal, oil, and natural gas) for a whole country and thus reflects the nation-wide resource procurement circumstance.

$$\text{Resource Import Dependency}_{it} = \sum_f \text{Net Import}_f \; / \; \text{Total Primary Fossil Fuel Energy Supply} \qquad \text{Eq. (Ⅲ-1)}$$

Coal includes hard, brown, and other subordinate[2] types. Oil includes crude oil, natural gas liquid, and feedstock. Natural gas includes total import via pipeline and liquefied, natural gas. Data for OECD countries were computed using IEA databases.[3] The index for each fossil fuel was calculated only for net importers. Net exporters' import dependency for a resource is denoted by 0.

2 Hard coal includes anthracite as well as coking, bituminous, and sub-bituminous coals. Brown coal includes lignite in Australia, Finland, France, and Portugal. In Canada, Germany, Hungary, Italy, the Netherlands, Norway, Spain, and the United Kingdom, brown coal includes sub-bituminous specimen.
3 International Energy Agency (IEA) (2011a, 2011c, 2011d, 2011e) offers the main data sources up to 2011 and updated data to 2013 were as indicated from the annual published reports from 2014 and later.

3.1.1.2 Generation

Supply reliability should include a measure for generation capacity that accommodates fluctuating demand. For the generation sub-sector, we choose reserve factor, which exhibits available operational capacity in the time of peak demand. It shows supply surplus level by the capacity to handle sudden increases in peak demand (Sheepers et al., 2007). This measure discerns a risk of possible power outages by generation supply deficit created by underinvestment (Sheepers et al., 2007).

$$\text{Reserve Factor}_{it} = \text{Capacity at Peak} / \text{Peak Demand} \quad \cdots\cdots\cdots \quad \text{Eq. (Ⅲ-2)}$$

Capacity at peak times for reserve factor calculation, as shown in Eq. (Ⅲ-2), depends not only on capacity investment level but also on the technology state of the equipment and operational capacity. It may be less than net maximum capacity due to unanticipated shutdowns, lack of water for hydro operations, and other factors (IEA, 2011b). Peak demand is the highest simultaneous demand for electricity satisfied in country i during the year t (IEA, 2011b). All available data sets for the reserve factor came from the IEA database.

3.1.1.3 Transmission and distribution

Supply reliability in the T&D sub-sector can be measured by the frequency and lengths of disruptions that arise in a transmission and distribution system. In this paper, we used disturbance time to measure the supply reliability in the T&D sub-sector; this term refers to the minutes in which electricity in unavailable in a network. It is standardized through measures of the T&D distance (km).

$$\text{Disturbance Time}_{it} = \text{The Unavailability of Network for Unplanned Disturbance(Min.)} / \text{Grid Length(Megameter)} \quad \cdots\cdots \text{Eq. (Ⅲ-3)}$$

Reasons for the disturbance times include overloads or failure in the T & D network as well as overloads, false operation, or failure of protection devices or other elements (UTCE, 2002). Quantifying unexpected disruption of an energy supply into an index can be accomplished by using the most representative, direct measures of supply reliability experienced by customers[4]. Data for unplanned disturbances time (minutes) and grid length (megameter) is based on the ENTSO-E Statistical Yearbook (UCTE, 2002-2007; RGCE, 2008; ENTSO-E, 2009-2013).

3.1.1.4 Electricity import

Electricity import provide a source of energy during a time of supply unreliability.

4 This study investigates the possibility of restructuring undermining the reliability of supply in each subsystem. That is, we explored the possibility that some form of disturbance occurring in each subsystem, although the actual supply disturbance does not take place. In this study, we distinguished the T&D network from other networks and used the unplanned disturbance time as a specified variable for this network. We would like to note, however, “disturbance time” is the result of the undermined reliability of supply that occurs in resources and generation, in respect to the stages of electricity supply, that manifests itself as the supply disturbance in the T&D network. In order to identify the effects of restructuring on actual supply disturbance, it is necessary to investigate how the reliability of supply is undermined in resource and generation stages prior to the T&D network, and further clarify their interconnectedness.

Specifically they are used when power plants within the national boundary do not produce energy and so the electricity is imported and delivered to end-users. Supplementing domestic supply with low levels of electricity import is considered a flexible way to improve response to demand in an internationally integrated electricity market (Sheepers et al., 2007).

On one hand, the flexible role of limited electricity imports is expected to improve supply reliability as it diversifies the national response to meet domestic demands. Accroding to EC, 10% import capacity interconnection, expressed as percentage of domestic production capacity is recommended for energy security of supply. On the other hand, excessive import dependency can cause supply disruption or price increase and fluctuation undermining supply vulnerability (Percebois, 2007). In summary, effects of electricity imports on energy security differ according to the proportion of demand met by foreign suppliers. Furthermore, an appropriate import share for flexibility or import dependency differs by country, which is one of the future potential research directions.

Eq. (Ⅲ-4) was used to calculate electricity import dependency (the ratio of the amount of electricity imports in the total consumption of country i and year t). Data for electricity import came from IEA databases (2011b; 2012b; 2013b; 2014b).

$$\text{Electricity Import}_{it} = \text{Electricity Import(KWh)}/\text{Total Electricity Consumption(KWh)}$$

Eq. (Ⅲ-4)

3.1.2 Indicators for restructuring

Electricity industry restructuring was measured via three aspects of regulatory reform: entry liberalization, privatization, and vertical divestiture. A restructuring index from the OECD International Regulation Database (Koske et al., 2015) was used to analyze types and progressions of regulatory reforms of the electricity industry. The degree of regulation in entry liberalization, a form of business ownership, and the degree of vertical divestiture in power generation as well as T & D were quantitatively measured and then computed as the weighted average of their sub-level indicators (Koske et al., 2015).

First, the entry liberalization indices was created based on three sub-level indicators: regulation on third party access (TPA), existence of liberalized wholesale market, and minimum consumption threshold for free choice of the supplier (Koske et al., 2015). Each sub-indicator carries the same weight, and the higher value is assigned, from 0 to 6, if the entry to market is more liberalized. For example, if TPA is mandatory (regulated TPA), a liberalized wholesale market is established, and no threshold is required to account for free choice of the supplier, then each sub-indicator has a value of 6, which indicates the most liberalized market entry.

Second, a form of business ownership was measured by the percentage of shares owned by the government in the largest corporations conducting business in generation/import, transmission, distribution, and supply segments of the electricity industry. The more privatized the firm, the higher value assigned (from 0 to 6) to it.

Third, the vertical structure of the electricity industry was measured by the level of vertical separation between a specific segment5 and other segments of the electricity sector: The values range from 0 (integrated) to 6 (separated). The detailed description of the restructuring indicators is found in Appendix 2.

To test multicollinearity in restructuring variables, entry liberalization, privatization and vertical divestiture which proceed at the same period in Europe, VIF test and condition index are conducted. According to test results, restructuring variables can be estimated in a regression equation and interpreted with coefficient with no significant multicollinearity.

3.2 Regression equations

To quantify relationships between electricity supply reliability in each sub-sector and degree of restructuring, we designed an econometric model. For each sub-sector, indicators of restructuring were assigned as important explanatory variables, and supply reliability indicators were assigned as dependent variables in the regression analysis. Inferring causal effect of restructuring on the resources sub-sector is shown in Eq. (Ⅲ-5), the generation sub-sector is presented in Eq. (Ⅲ-6), the T&D sub-sector in found in Eq. (Ⅲ-7), and the electricity import sub-sector is illustrated in Eq. (Ⅲ-8).

$$\text{Resource Import Dependency}_{it} = \gamma_0 + \gamma_1\text{Entry Liberalization}_{it} + \gamma_2\,\text{Privatization}_{it} + \gamma_3\text{Vertical Divestiture}_{it} + \gamma_4\text{Eletricity Consumption}_{it} + \gamma_5\text{Population}_{it} + \gamma_6\text{GDP}_{it} \cdots \text{Eq. (Ⅲ-5)}$$

$$\text{Reserve Factor}_{it} = \delta_0 + \delta_1\text{Entry Liberalization}_{it} + \delta_2\,\text{Privatization}_{it} + \delta_3\text{Vertical Divestiture}_{it} + \delta_4\text{Eletricity Consumption}_{it} + \delta_5\text{Population}_{it} + \delta_6\text{GDP}_{it} \cdots \text{Eq. (Ⅲ-6)}$$

[5] generation/import, transmission, distribution, and supply segments of the electricity industry

$$\text{Disturbance Time}_{it} = \eta_0 + \eta_1 \text{Entry Liberalization}_{it} + \eta_2 \text{ Privatization}_{it} + \eta_3 \text{Vertical Divestiture}_{it} + \eta_4 \text{Eletricity Consumption}_{it} + \eta_5 \text{Population}_{it} + \eta_6 \text{GDP}_{it} \quad \cdots \text{Eq. (III-7)}$$

$$\text{Electricity Import Dependency}_{it} = \theta_0 + \theta_1 \text{Entry Liberalization}_{it} + \theta_2 \text{ Privatization}_{it} + \theta_3 \text{Vertical Divestiture}_{it} + \theta_4 \text{Eletricity Consumption}_{it} + \theta_5 \text{Population}_{it} + \theta_6 \text{GDP}_{it} \quad \cdot \text{Eq. (III-8)}$$

To control each nation's characteristic electricity production and consumption scales, levels of electricity consumption (electricity production), population (electricity demand), and GDP (electricity demand) were set as control variables in each equation. The control variable data sets came from the open-access World Bank database. GDPs are deflated at 2005 constant price (in U.S. dollars) using the GDP deflators that were published by World Bank. We expect that supply reliability will be illustrated by shortfalls experienced as the electricity production and demand scales of a country increase because large-scale industries tend to reflect many risks that must be controlled from both production and demand sides.

There might be a further suggestion on how some variables included in the regression equation could be relevant in the introduction of renewable energy sources. For purposes of this paper, nonetheless, the period we investigated did not yield significant results in respect to the impact of renewable energy sources on relevant variables, due to insufficient introduction of renewable energy sources. In the future, however, when the supply of renewable energy sources would rise significantly and the integration of the electricity market would be further along, and also due to the intermittence of the renewable energy sources, the electricity exports could increase. In this case, the impact of the introduction of renewable energy on relevant variables could be observed and the effects of restructuring could be different.

3.3 Sample data

We used panel data from 15 OECD countries obtained from 1987 to 2013. The data coverage depended on the availability of regulatory reform data. Because the data are available only from 2002 for UTCE member countries, inputs for data for the T&D sub-sector could be collected for 8 European countries from 2002, and 3 countries were added to the database after 2009. Hence, unbalanced panel data were used for this research. Summarized descriptions and descriptive statistics for the data set are shown in Table Ⅲ-1. Information from select countries and the mean values of the main variables by nation are shown in Appendix 3. According to the correlations shown in Appendix 4, control variables representing national scales of production and consumption were high. However, most of the explanatory variables were associated with low correlation value.

3.4 Estimation method

Random- and fixed-effect models for panel data analysis were used to estimate Eqs. (Ⅲ-5) – (Ⅲ-8) (Greene, 2011). Because the resource import dependency and electricity import (dependent variables), which include net export per country, are censored at zero, a tobit model is the appropriate choice to handle this problem (Greene, 2011). Honore (1992) suggested a way to estimate a fixed-effect panel tobit model in which the estimator shows consistency. The Hausman test was performed on each equation to test the validity of choosing either a random-effect or a fixed-effect model. In this analysis, a random-effect model was chosen for all equations over fixed-effect models that did not lead to rejection of the null hypothesis: Differences in coefficients showed no systematic pattern. For each equation, the null hypothesis states that a covariance matrix that is diagonal (zero covariance between equations) is not rejected. The following values from χ^2 the distribution in the Hausman tests indicate an accepted null hypothesis: 1.66 (for resource import dependency), 2.06 (for reserve factor), 5.87 (for disturbance time), and 0.55(for electricity import). This finding means that the particular explanatory variables (restructuring) are not correlated with nation-specific effects.

Table Ⅲ- 1. Descriptive statistics

Sub-sectors	Variables	Description	Data source	Mean (s.d.)	Min.	Max.
Resources	Resource Import Dependency	Range from 0 to 1, net exporter's import dependency is marked with '0'	IEA	0.50 (0.32)	0.00	0.99
Generation	Reserve Factor	Available operational capacity in the time of peak demand	IEA	1.19 (0.18)	0.74	1.75
T&D	Disturbance Time	Duration of unplanned disturbance (Min/Mm), standardized with T&D distance	UTCE	0.01 (0.03)	0.00	0.25
Electricity Import	Electricity Import Dependency	Range from 0 to 1	IEA	0.08 (0.08)	0.00	0.42
Restructuring Variables	Entry Liberalization	Range from 0 to 6 with weighted average of low-level indicators	OECD	3.38 (2.74)	0.00	6.00

	Privatization	Range from 0 to 6 with weighted average of low-level indicators	OECD	2.344 (2.24)	0.00	6.00
	Vertical Divestiture	Range from 0 to 6 with weighted average of low-level indicators	OECD	0.91 (0.84)	0.00	3.56
Control Variables	Electricity Consumption	Total amount of electricity consumption (TWh)	World bank	496.08 (872.35)	20.64	4154.97
	GDP	Gross domestic production based on 2005 USD (trillion) constant prices	World bank	1.82 (2.73)	0.07	14.45
	Population	Million persons	World bank	54.36 (69.26)	4.19	316.13

4. Results

Model 1, shown in Table Ⅲ-2, provides the estimation result of Eq. (Ⅲ-5), which we used to analyze the relationship between supply reliability and restructuring in the resources sub-sector. The coefficient for privatization on resource import dependency is positive (0.013) at 1% statistical significance; however, the other restructuring variables do not exhibit significant relationships with resource import dependency. This finding implies that the business ownership with more privatization elements experience greater resource import dependency. When the maximum value of privatization was multiplied by 6, the coefficient (0.014) indicated that resource import dependency increased 8% to 58% from mean value(50%) of data. Because greater resource import dependency entails an impediment in supply reliability due to greater risk of interruption or price hike, restructuring in the form of privatization exerts a negative effect on continuous reliable supply. The finding comports with conclusions by Palm (2008): Policy objectives that advocate for national energy supply security in the resources sub-sector may not match the agenda of individual privatized firms.

Model 2 shows the estimation result of Eq. (Ⅲ-6), which was used to investigate the relationship between supply reliability and restructuring in the generation sub-sector. It shows a negative and significant coefficient value (–0.028) on entry liberalization at a 1% significance level and (−0.063) on vertical divestiture at the 5% significance level, but a positive significant coefficient value (0.025) at the 10% level when reserve factor is the dependent variable. Findings show that a decrease in reserve factor indicates a reduced ability to respond in times of peak demand and a heightened possibility of disruption in electricity supply. The coefficient value means that the maximum value (6) of entry liberalization is associated with a reserve factor decrease of approximately 0.17 from the value obtained when the least liberalized market degree is measured (at minimum value of 0). The decreased value (1.02) can indicate a serious interruption if the mean value (1.19) of the reserve factor drops as entry liberalization is completed. Although it is almost offset by maximum privatization level (6), vertical divestiture (maximum value of 3.56) also hinders the supply margin as it is decreased by 0.22. The closer the reserve factor gets to 1, the higher the possibility of supply interruptions. Hence the result affirms that restructuring in the form of liberalized entry and vertical divestiture have a detrimental effect on supply reliability (Botterud and Doorman, 2008; Gugler et al., 2013; Joskow and Tirole, 2007).

Model 3 was used to determine the casual relation between restructuring and supply reliability in the T&D subsector. One might expect normalized disturbance time to relate with ownership unbundling, but it this is not supported by the findings, which show no statistically significant values.

Model 4 shows the regression result of Eq. (Ⅲ-8), which we used to evaluate the relationship between supply reliability in terms of electricity import dependency and restructuring. Both entry liberalization and vertical divestiture have a statistically significant (at 1% and 5% levels) coefficient value (0.012) and (−0.013), but their effects have opposite signs. Entry liberalization exhibits a positive causal relation with electricity import dependency. With a maximum value (6) of entry liberalization, the coefficient is associated with an electricity import share increase of 15%, which can be interpreted as improving demand response. Normally limited electricity imports enhance the supply flexibility, but the outcome depends on the level of electricity market integration. In addition, we found a negative relationship between vertical divestiture and electricity import dependency. The vertical divestiture was associated with a decrease in electricity imports of 3.40%—from a mean value of 8% of electricity import share—as calculated with a maximum value (3.56) of vertical divestiture.

Table Ⅲ- 2. Restructuring and reliability (Random-effect model)

	Dependent variables			
	Model 1 (Tobit)	Model 2	Model 3	Model 4 (Tobit)
Explanatory variables	Resource Import Dependency	Reserve Factor	Disturbance Time	Electricity Import
Entry liberalization	4.210e-04 (0.002)	-0.028*** (0.008)	-0.007 (0.006)	0.012*** (0.002)
Privatization	0.013*** (0.003)	0.025* (0.014)	0.002 (0.002)	-0.001 (0.002)
Vertical divestiture	-0.008 (0.007)	-0.063** (0.027)	-0.008 (0.008)	-0.013** (0.006)
Electricity consumption	-3.390e-04*** (8.69e-05)	-9.77e-07 (3.171e-04)	7.86e-05 (9.94e-05)	6.86e-05 (6.52e-05)

Population	-0.003 (0.002)	-0.013*** (0.005)	0.001 (0.001)	-4.851e-04 (0.001)
GDP	0.127*** (0.019)	0.361*** (0.128)	-0.032 (0.021)	-0.024** (0.012)
Constant	0.470*** (0.067)	1.357*** (0.053)	0.047 (0.034)	0.070** (0.036)
No. of observation	385	191	101	385
Wald Chi-sq, p-value	0.00	0.00	0.05	0.00

The standard errors are in parentheses. * p<0.1, ** p<0.05, *** p<0.01

As entry liberalization has a negative causal relationship with reserve factor, the result attests that an increase in competition as part of restructuring negatively affects the steady supply of electricity. However, findings indicate an increase in shares of electricity import; hence, an increase in flexibility of energy supply shows a positive effect on reliability. Entry liberalization that aims to promote competition, could induce lowered reserve factor, as incumbents are incentivized to increase operating rate of existing capacity rather than to invest in capacity building. In the aspect of electricity imports, entry liberalization could also allow entrants to gain access to market without capacity building, increasing the electricity imported in the process.

The restructuring that shifts business ownership into a more privatized one increases dependency on resource imports, but it improves reliability in the generation sector by increasing the reserve margin. However, privatization results in decentralized power that may require that government hold firms accountable for producing reliable electricity (Palm, 2008). Meanwhile, government intervention to improve X-inefficiency of public ownership may result in adverse outcomes in the generation sub-sector (Gugler et al., 2013).

The vertical divestiture shows negative causality with the reserve factor and electricity import. It results from the failure of the internalization of vertical externality and coordination. Vertically integrated firms often cannot meet the demand and hesitate to invest in new capacity until future demand is made clear. Also, to avoid transaction costs, separated firms may not import electricity from foreign firms.

Restructuring exerts differing effects by type. According to the result of this research, restructuring, which is designed for improving efficiency, is associated with some partly adverse outcomes, especially on domestic electricity supply reliability.

5. Discussion

When the ownership structure changes through privatization, the incongruence of objectives between the firms governed by the state and those owned by individual businesses causes a negative effect in the reliability of supply sectors such that government oversight may be required. Privatization accompanying a change in operational objectives implies that pursuit of profit by an individual enterprise may interfere with the goal of a stable national electricity supply system. Certain objectives, such as managing the import dependency level, which is usually beyond the scope of businesses, cannot be guaranteed by voluntary efforts of enterprises and requires a public policy approach. Therefore, an integrated managerial system must be devised at the national level to assure steady operation of a system for energy supply after privatization.

Restructuring, which allows entrance of new enterprises and subsequently changes the existing competitive ecosystem, may cause underinvestment in capacity. This, in turn, undermines supply reliability. The short-term goal of maximizing profit through achievement of a higher operation ratio in existing capacity may result in underinvestment in capital and damage the reliability of the energy supply in the long term. Creation of an incentive system is necessary to resolve issues of underinvestment in generation capacity as the result of increasing competition.

Discussions on the generation sub-sector must involve ways an increased reserve factor can help attain supply reliability without countering efficiency. That is, an increase in reserve factor may lower the operation ratio of capacity and therefore can negatively affect efficiency levels.

As the degree of efficiency varies based on the reserve margin of a particular country and organization of power plants, it also depends on an agreed-upon level of reserve factor, thereby reflecting unique national characteristics. Aside from the direct discussion on efficiency, this research attests to the negative effect of restructuring on supply reliability due to an increase in the operation ratio created by a pursuit of efficiency in the short term, the problem of underinvestment in the long term, and subsequent adverse effect of reduction in reserve factors on the reliability of supply.

The effect on electricity imports differs depending on the types of restructuring. A new entrant could increase the electricity import share of the nation, which could increase the new firm's chance to enter the market without investing in capacity for generation. However, a firm separated through vertical divestiture could decide to contract a domestic firm and thus reduce transaction costs and decrease electricity imports. Such action by a divested firm could hurt the nation by avoiding the imports that can improve demand response ability.

Approximately 20% of electricity import share could play an important role in improving the ability to respond to demand. Therefore, entry liberalization has a positive effect and vertical divestiture has a negative effect on supply reliability. However, an excessive dependency on imports increases the possibility of disruption in supply; therefore, future research on the effect of imported electricity on supply reliability and the extent to which imported electricity has a positive impact on supply reliability is required. As electricity trade among nations becomes more prevalent and market integration is increasingly undertaken, the need for investigation in the role of imported electricity will be continuously required.

Because the various types of restructuring exert inconsistent effect, their impact on electricity supply sectors varies. One must be aware that restructuring with a particular objective may not engender an expected outcome, and the final outcome may yield an unwanted result. Hence a more comprehensive understanding on net effect is required.

As Table Ⅲ-1, the average value of restructuring variables are 3.38 for entry liberalization, 2.34 for privatization and 0.91 for vertical divestiture. These show that regulation reform is not completed and still in progress. Especially maximum valute of vertical divestiture, 3.56, means no legal separation firm exist in analysis target countries. According to this results, this paper can only suggest the causality between resturucturing and reliabilty in the middle step of regulation. After regulation completed, market with higly integrated and saturated demand can be a factor in future research on reliability with market structural change.

Overall conclusions

1. Summary and contribution

The energy security of a country is affected by conditions regarding the supply, demand, and conversion of energy and the consumer environment. The current research confirmed that in the primary energy sector, especially fossil fuel, like gas, the energy security that a country faces might be affected by internal conditions based on geopolitical factors. These geopolitical factors are major factors that determine bargaining power during gas supply contracts, which are often long-term mutual contracts. As such, the energy security of the supply of a primary energy source is within the influence of internal power that occurs naturally from a nation's standpoint. On the other hand, the domestic institutional environment surrounding the energy market showed an influence on supply conditions, and was revealed as a factor of bargaining power for certain countries. This implies that the bargaining power of a particular country has room to change according to the energy market structure. The extent of influence of the institutional environment on the level of energy security may differ according to sectors; and within the subdivision of energy conversion, the influence of the institutional environment on supply stability differs according to sectors.

The aim of the current research is to define the term "energy security" and to determine how it is analyzed within the context, beyond prior discussions. This research goes beyond those barriers in many ways. First, different from the existing framework of discussing the topic of energy security within the realm of resource economics, this research analyzed the topic as an energy issue as part of non-traditional security within international political economics. This can be comprehended as a geopolitical perspective, since the ownership, delivery, demand, market, and contract sectors cannot be separated from geopolitical conditions. In other words, the current research explained energy security at the crossroads of resource economics, international political economics, and geopolitics. This is due to the effort in figuring out the core of bargaining power during energy supply contracts.

Second, the current research examined the borderline between the two different goals of institutional environment and energy supply environment. The reorganization of the energy market, which started around the 1990s, was initiated as a neoliberalist solution for maximizing efficiency, but in terms of supplying energy, these changes in the institutional environment posed a threat to energy stability and proved that it might affect the level of energy security. Energy security is a domain that requires distinct functions of a specific country and cannot be measured with efficiency, and therefore, this research explained a phenomenon that occurs on the borderline of the energy security and systematic domains.

Third, this research applied a model that allows an accurate analysis and deep explanation beyond the methodological realm. Previous findings about the comparisons among Northeast Asian PNG routes were mostly dominant judgments based on cost economics. Network games were applied in order to reflect the connecting structures of the probable pipeline routes in Northeast Asia, and this proved to be a good method for explaining the continuing discussion on the pipeline routes. The contract price estimation model introduced a method that could identify various potential factors with only a few observations. This is meaningful in that it introduced and verified a recent non-traditional method in areas that cannot be solved through the traditional methods. In addition to identifying the logic of supply and demand, contract price estimation model is an alternative method for identifying the potential variables in determining the price, which makes it more meaningful.

2. Limitation and future research

Current research started with an interest in energy security within the field of resource economics, international political economics, and geopolitics. Narrowing down this multi-disciplinary phenomenon into one disciplinary interpretation may mislead the essence of the concept and narrow the perspective. The current research approached the fundamental cause of the issue without being bound by this traditional disciplinary domain. However, the framework of the analysis and the methodology are difficult to merge. Therefore, a coherent and systematic theoretical framework and methodology is necessary in order to explain the complex and multi-layered phenomenon. Geopolitics in particular is highly appropriate for explaining the phenomenon, which is observed in fossil fuel supply, but cannot be developed further beyond that point due to an insufficient theoretical basis.

With the appearance of novel resources, termed unconventional resources, and the change in their routes, the international political economic status of a country may change accordingly, and due to issues of migration, local markets may become integrated. In this context, the very first strategic step a country should take needs to be based on an understanding of geopolitics. In order to do that, a theoretical system and analysis on the internal power structure that a country faces needs to be established.

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Appendix 1: Correlation

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
X1	1												
X2	0.9912***	1											
X3	0.2253	0.1992	1										
X4	0.2313	0.2221	0.9880***	1									
X5	-0.0626	-0.0688	0.1409	0.1328	1								
X6	-0.0125	-0.0307	0.1277	0.105	0.032	1							
X7	-0.0538	-0.0533	-0.0469	-0.0458	-0.1405	0.5370***	1						
X8	-0.0008	-0.0025	-0.3461**	-0.3493**	0.0667	-0.1778	-0.0798	1					
X9	0.2479	0.2523	0.0427	0.0464	-0.1585	-0.2542	-0.1913	0.16	1				
X10	-0.3547**	-0.3581**	0.3546*	0.3468**	-0.023	-0.147	-0.156	0.0466	0.4897***	1			
X11	0.4006**	0.3902**	0.4421***	0.4435***	0.1558	0.0478	-0.1396	-0.1866	0.3401**	0.2193	1		
X12	-0.3185*	-0.2907*	-0.4156**	-0.3966**	0.0523	-0.1669	-0.0424	0.2915*	0.181	0.0384	-0.1184	1	
X13	0.5963***	0.5861***	0.182	0.1848	0.2680*	0.1242	0.002	0.1139	0.0247	-0.1894	0.5313***	-0.0342	1
X14	0.5094***	0.5014***	0.1213	0.1221	0.2003	0.211	0.0889	-0.1089	0.0608	-0.1326	0.5079**	-0.2905*	0.6804***
X15	-0.0578	-0.025	0.2526	0.2917*	0.1659	0.0399	-0.1019	-0.2043	0.09	0.1896	0.2426	-0.0052	0.214
X16	0.1535	0.1597	-0.1276	-0.1216	-0.0536	-0.0556	-0.1508	-0.0518	0.3300*	0.1113	0.7485***	0.1657	0.3852**

X17	-0.1537	-0.1453	-0.1614	-0.1609	0.0084	0.1505	0.1892	-0.1727	-0.4270***	-0.2843*	-0.3375**	-0.3828**	-0.5041***
X18	0.1671	0.1715	-0.0868	-0.0903	0.005	0.0031	0.0679	-0.2742*	-0.2734*	-0.2881*	-0.1429	-0.5020***	-0.2556
X19	-0.0124	-0.0054	-0.1478	-0.152	-0.034	-0.0018	0.0816	-0.2404	-0.3283*	-0.2611*	-0.3165*	-0.4272***	-0.4389***
X20	0.6685***	0.6568***	0.2753*	0.2793*	0.1557	0.0189	-0.0779	-0.0446	0.3127*	-0.0128	0.7483***	-0.134	0.8252***
X21	0.3708**	0.3705**	-0.1254	-0.1281	-0.1541	-0.0197	0.1391	0.1826	0.1068	-0.1629	0.2042	-0.0361	0.1826
X22	0.7341***	0.7300***	0.1247	0.127	0.0337	0.0407	0.0019	-0.017	-0.0179	-0.2574	0.3609**	-0.5459***	0.4053**
X23	0.2387	0.2147	0.9963***	0.9871***	0.1451	0.0863	-0.1037	-0.3000*	0.0627	0.3637*	0.4573***	-0.3975**	0.2068
X24	0.1282	0.1023	-0.0497	-0.081	0.2174	-0.5172***	-0.5771***	0.4409***	0.2362	0.0745	0.1418	0.0876	0.2372
X25	-0.0173	-0.0756	-0.0285	-0.1065	0.2904*	-0.5849***	-0.5045***	0.0397	0.0544	0.0093	0.0987	0.0552	0.0377
X26	-0.0093	-0.1242	0.1879	0.0485	0.0981	0.1322	0	0	-0.0224	0.0936	0.04	-0.2425	0

	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26
X14	1												
X15	0.1969	1											
X16	0.4336***	0.2114	1										
X17	-0.19	-0.3565**	-0.3218*	1									
X18	0.0394	-0.2824*	-0.1984	0.8113***	1								
X19	-0.1654	-0.3104*	-0.3186*	0.8706**	0.9703***	1							

X20	0.8135***	0.2072	0.5514***	-0.5103***	-0.2143	-0.4443***	1						
X21	0.1242	-0.4429***	0.1957	-0.0704	0.0076	-0.0474	0.2196	1					
X22	0.4961***	-0.0593	0.1589	0.2719*	0.5770***	0.4134**	0.4678***	0.2986*	1				
X23	0.1186	0.2583	-0.1088	-0.1902	-0.1043	-0.1678	0.2909*	-0.1188	0.1299	1			
X24	-0.029	-0.0935	0.1495	-0.2358	-0.0534	-0.089	0.1615	0.1253	0.0636	0.017	1		
X25	-0.0562	-0.1171	0.1152	-0.1019	0.0531	0.033	0.0635	0.0195	-0.0249	-0.0019	0.6986***	1	
X26	0	-0.1703	-0.0678	-0.0367	0	-0.0009	0.0036	0	0	0.1675	0.2072	0.5237***	1

* p<0.5,**p<0.01, *** p<0.001

Appendix 2: Regulatory reform index

The OECD International Regulation Database provides indicators useful for measuring regulatory restrictions in energy, transportation, and communication. The indicators cover T&D and supply in the electricity industry. They include the following low-level measures in the electricity industry: barriers to entry, public ownership, and vertical integration.

The indicators for entry regulation focus on terms and conditions for third party access (TPA) and the extent that consumers may choose their suppliers. Regulated TPA, free consumer choice, and a liberalized wholesale power market presumably promote competition. The indicator for public ownership records the prevailing ownership structure, which ranges from fully private to fully public. The indicators for vertical integration reflect the status of electricity generation and supply compared to natural monopoly activities. The degree of separation ranges from full integration to legal and accounting separation to separation into different companies owned by different shareholders. The assumption, reflecting industrial organization theory, is that the scope for anticompetitive behavior is largest when an electricity or gas company simultaneously controls the network and operates in upstream or downstream competitive markets (Conway and Nicoletti, 2006).

We use three kinds of liberalization indices: entry liberalization, privatization, and vertical separation based on the weighted averages of the sub components of each category. The value of them ranges from 0 to 6 and correspond with the degree of liberalization from least to greatest. The specific contents and weights are given in table below.

Indicators for liberalization in the electricity industry

<table>
<tr><th>Liberalization Measures</th><th>Questions</th><th>Weights</th><th colspan="6">Liberalization Degree</th></tr>
<tr><td rowspan="6">Entry Regulation</td><td rowspan="2">How are the terms and conditions of third party access (TPA) to the electricity transmission grid determined?</td><td rowspan="2">1/3</td><td colspan="2">Regulated TPA</td><td colspan="2">Negotiated TPA</td><td colspan="2">No TPA</td></tr>
<tr><td colspan="2">6</td><td colspan="2">3</td><td colspan="2">0</td></tr>
<tr><td rowspan="2">Is there a liberalized wholesale market for electricity?</td><td rowspan="2">1/3</td><td colspan="3">yes</td><td colspan="3">No</td></tr>
<tr><td colspan="3">6</td><td colspan="3">0</td></tr>
<tr><td rowspan="2">What is the minimum consumption threshold that consumers must exceed to be able to choose their electricity supplier? (Gigawatts)</td><td rowspan="2">1/3</td><td>No Threshold</td><td>< 250</td><td>250-500</td><td>500-1000</td><td>>1000</td><td>No Consumer Choice</td></tr>
<tr><td>6</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
</table>

<table>
<tr><td>Privatization</td><td>Where the percentage of shares except owned, either directly or indirectly, by the government in the largest firm in sector?</td><td>1</td><td colspan="4">% of shares not owned by public sector/100×6</td></tr>
<tr><td rowspan="2">Vertical Separation</td><td rowspan="2">What is the degree of vertical separation between a certain segment of the electricity sector and other segments of the industry?</td><td rowspan="2">1</td><td>Ownership Separation</td><td>Legal Separation</td><td>Accounting Separation</td><td>No Separation</td></tr>
<tr><td>6</td><td>4.5</td><td>3</td><td>0</td></tr>
</table>

Appendix 3: Mean values of descriptive variables

Mean values of main variables

Country	Resource Import Dependency	Reserve Factor	Disturbance Time	Electricity Import	Entry Liberalization	Privatization	Vertical Divestiture
Australia	0.06	1.28	-	0.00	3.94	0.17	0.50
Canada	0.00	1.22	-	0.03	2.81	0.00	0.89
Finland	0.55	1.06	0.002	0.15	4.12	1.81	1.36
France	0.49	1.08	0.020	0.02	2.94	0.24	0.60
Germany	0.52	1.31	0.024	0.07	3.11	4.78	0.63
Greece	0.81	1.20	0.013	0.07	2.43	1.30	0.75

Hungary	0.53	1.31	0.003	0.27	2.53	2.06	1.01
Italy	0.85	1.14	0.013	0.15	2.80	1.81	1.04
Japan	0.82	1.11	-	0	3.05	5.78	0.31
Netherlands	0.90	1.38	0.000	0.16	3.28	0.89	0.83
Norway	0.02	1.14	0.000	0.05	5.11	1.50	0.90
Portugal	0.80	-	0.004	0.13	3.20	2.41	1.57
Spain	0.74	1.03	0.022	0.03	3.53	3.73	1.39
United Kingdom	0.15	-	0.015	0.04	5.12	4.55	0.94
United States	0.33	-	-	0.01	2.68	4.57	0.86

Appendix 4 : Correlation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1)	1.00									
(2)	0.13	1.00								
(3)	0.17	-0.19	1.00							
(4)	0.01	0.29	-0.27	1.00						
(5)	-0.06	-0.04	-0.05	-0.04	1.00					
(6)	0.44	-0.23	0.39	-0.13	0.04	1.00				
(7)	0.23	-0.35	0.09	-0.13	0.23	0.75	1.00			
(8)	0.35	-0.06	0.24	-0.46	0.22	0.55	0.59	1.00		
(9)	0.54	-0.00	0.28	-0.31	0.14	0.68	0.61	0.95	1.00	
(10)	0.49	-0.05	0.22	-0.38	0.20	0.52	0.54	0.98	0.97	1.00

Note: (1) Resource import dependency, (2) Reserve factor, (3) Disturbance time, (4) Electricity import, (5) Entry liberalization, (6) Privatization, (7) Vertical divestiture, (8) Electricity consumption, (9) Population, (10) Gross domestic product

Abstract (Korean)

본 논문은 에너지 안보의 경계를 둘러싸고 발생하는 현상을 정확하게 설명하기 위한 방법론을 도입하고 이를 통해 현상의 근원적 원인을 파악하고 해석하는 것에 그 목적이 있다. 전통적인 안보의 개념이 '국가(nation-state)' 가 행하는 '군사력' 을 바탕으로 한 물리적 영토 중심의 '국가 안보'를 목적으로 하고 있는 것에 대응하여 본 논문에서는 비전통 안보(non-traditional security)가 '초국가적(supra-state)' 혹은 '국가 내부(intra-state) 행위자'에 의해 '비군사적 영역' 에서 나타날 수 있는 '인간 안보(human security)'를 개념화하고 있는 것에서부터 논의를 시작하였다. 에너지의 공급은 그것을 달성하지 못한 상태가 가져오는 피해의 심각성과 그 파급력으로 인해 개인의 복지와 직접적인 관련성을 가지고 있으며, 이러한 비 안보 상황의 개선을 위해서 국가 간의 협력과 같은 초국가적 행위나 국가 내부에서의 조정을 요하기도 한다. 그러나 현대 사회의 동력원으로 큰 비중을 차지하고 있는 화석연료의 공급은 여전히 국가 정책의 중요한 부분이며, 에너지의 공급에서 발생하는 문제는 그 원인이 지정학적 요인으로 지적되고 있다. 즉, 에너지 안보의 문제는 국가의 문제이기도 하면서 그것을 넘어서기도 한다. 이러한 현상의 분석은 자원 경제, 국제 정치 경제, 지정학의 전통적인 경계 너머에서 총체적으로 다루어질 필요가 있다. 본 논문은 이러한 에너지 안보를 둘러싼 전통적인 경계를 넘는 세 가지 현상에 관한 분석을 주제로 하고 있다.

첫 번째 주제는 동북아로의 러시아산 파이프라인 가스의 도입이 가시화됨에 따른 파이프라인의 연결 구조에 관한 것이다. 파이프라인의 건설을 통한 가스의 공급은 노선에 참여하는 각국의 협력을 통해 지역 에너지 공급을 충족시키는 비전통 안보의 이슈로 드러나지만 특정 국가의 경유 여부를 결정하는 데 있어 국익이 결부되며 국가 간 대립이 나타날 수 있는 영역이기도 하다. 이러한 파이프라인 노선의 연결 구조를 반영하여 동북아에서 나타날 수 있는 옵션의 비교를 위해 네트워크 게임과 링크 중심 가변 네트워크 배분 규칙(Link-based Flexible Allocation Rule)을 활용하였다. 이를 통해 러시아산 파이프라인 가스의 동북아로의 공급 노선에 따라 각국에 배분되는 가치와 협상력을 평가할 수 있었다. 또한 이 모델의 결과를 통해 동북아에서 나타나는 '러중남' 노선과 '러북남' 노선의 논의가 중요하게 다루어지는 현상을 설명할 수 있었다.

두 번째 주제는 장기 쌍무적 계약(Long-term bilateral contract)으로 이루어지는 가스 거래에서 계약 가격을 결정하는 요인에 관한 것이다. 한 국가의 에너지 공급을 충족시키기 위한 가스 공급 계약은 기업 수준에서 이루어지지만 정치적 재화(politicized commodity)로 인식되는 천연자원의 거래라는 측면에서 국가 특성에 기반한 협상력에 의존적이다. 계약 가격을 결정하는 다양한 잠재적인 요인 중에서 큰 영향을 미치는 요인들을 식별해내기 위하여 본 논문에서는 벌점화 축소 추정 기법(Least Absolute Shrinking and Selection Operator)과 이중선택(double selection)을 활용하였다. 전통적인 계량 모델이 고차원 데이터의 해석에서 보이는 한계를 극복하기 위해 대안적인 접근법을 활용하였고, 이를 통해

계약 가격에 주요한 영향을 미치는 변수를 식별할 수 있었다. 공급국 우위가 나타나는 장기 쌍방 계약에서 공급국의 시장지배력에 대응할 수 있는 수요국의 시장 구조는 협상력에 주요한 영향을 주는 것으로 나타났다. 또한 수송거리가 멀어 비용이 높아지는 경우 수요자는 이에 대한 보전을 계약에서의 협상력으로 활용할 여지가 있다는 결과가 나타났다. 이를 통해 공급국과 수요국의 협상력의 근원이 자원의 특성에 기인하는 지정학적인 요인에서 비롯됨을 확인하였다.

세 번째 주제는 발전(generation) 부문에서의 에너지 안보와 제도적 환경의 상관관계에 관한 것이다. 국가의 경계로 인식되는 전통적인 안보의 영역이 국가 내부 특정 부문의 에너지 안보로 확장되는 현상을 분석하고자 하였다. 본 논문에서는 경쟁 구조의 변화, 소유구조의 변화, 시장 구조의 변화가 전력 산업의 각 하위 부문의 공급안정성에 미치는 영향력을 판단하고자 하였다. 전력 부문 에너지 안보 수준의 측정을 위해 부문별 공급안정성을 나타내는 지표를 선정하고, 이것이 전력 시장 구조개편과 어떠한 인과관계를 나타내는지 확률효과모형(Random effect model)을 통해 파악하고자 하였다. 이를 통해 효율성 개선을 목표로 진행된 제도 환경의 변화가 에너지의 안정적 공급이라는 전환 부문의 고유한 목적에 영향을 미칠 수 있음을 확인하였다.

주요어 : (에너지 안보, 비전통 안보, 동북아 파이프라인 가스 노선, 계약 가격 결정 요인, 공급 안정성)
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