Geopolitics of Trans-boundary Infrastructure:

A Network Game Analysis of Natural Gas Pipeline Plans

（ネットワークゲームを用いた越境インフラストラクチャーの地政学的分析：

国際天然ガスパイプライン計画が相対的交渉力に与える影響）

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長山　大介

Daisuke Nagayama

Ph.D. Candidate

(Supervisor: Professor Masahide Horita)

Department of International Studies

University of Tokyo

Abstract

Natural gas is an important source of relatively low-emission and low-cost, non-nuclear, readily abundant energy, but the difficulty of storage and transportation add a geopolitically and geostrategically complex aspect to the international trade of this resource. Most of global natural gas trade is through natural gas pipelines, which is an infrastructure that is strictly specific to the transportation of natural gas, and thus the very structure of its network can dictate the strategic relationship among countries involved in its trade.

This thesis has applied a network game model in which these pipeline networks are modeled as graphs and respective value functions, and employed the Link-based Flexible Network (LBFN) Allocation Rule as the solution concept. The LBFN Allocation Rule is an improvement over the Myerson Value, which is a network game application of the Shapley Value. This thesis interpreted the LBFN Allocation as the relative power structure, or the "Relative Bargaining Power" among these natural gas trading countries.

This thesis then conducted calculations and performed analyses on the case of trade between Russia, Ukraine, Belarus and Western Europe. The calibration was partially borrowed from existing work by Hubert and Ikonnikova (2011) which analyzed the same countries and employed a cooperative game model and the Shapley Value as the solution concept.

The results were then compared to Hubert and Ikonnikova (2011) in order to evaluate the analytical flexibility that the Network Game Model and the LBFN

Allocation Rule have over the Cooperative Game Model and the Shapley Value as a solution concept. While the latter was unable to model Ukraine and Belarus as consumers of natural gas as well as transit countries, and was also unable to model Western Europe as a strategic importing player, the Network Game Model allowed for this, as well as identified the power that each of the pipelines bestowed upon the players that governed these pipelines. A comparison was made between a setup using the Network Game and the LBFN Allocation Rule in which the conditions closely replicated that of Hubert and Ikonnikova (2011) and the setup proposed in Nagayama and Horita (2011) in order to confirm that under similar conditions, the two models would yield similar results.

Further, this thesis searched for empirical evidence by assuming that a change in pipeline network structure or a “credible” pipeline plan affects the Relative Bargaining Power of countries within the network structure, and that the change in Relative Bargaining Power would be reflected upon the negotiations that these natural gas trading countries engage in. Both a qualitative and quantitative analyses were conducted in order to confirm the degree to which the model employed in this paper is able to explain the complex string of events.

The paper was indeed able to identify a change in the relative price of natural gas between Western Europe and the two transit countries (Ukraine and Belarus) in the years after the announcement of the Nord Stream Pipeline, which was in line with what is predicted by the Relative Bargaining Power computed by the LBFN Allocation Rule for the Status Quo Scenario and the scenario in which Nord Stream Pipeline is built.

The paper was able to (i) model transboundary natural gas trade as a Network Game, (ii) apply the LBFN Allocation Rule and conduct computations, and (iii) find empirical evidence that the change in natural gas pipeline structure had an influence on bargaining power and the relative natural gas prices.

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1 Introduction

1.1 Growth in Global Energy Consumption

The modern world, with a population of over 7 billion and expanding evermore rapidly, is operated by consuming enormous amounts of energy in various forms. The electricity that we use at every corner of our homes, offices and schools is generated at power plants that change fossil fuels, nuclear resources, or renewable energy in some cases, into electric power. The automobiles, airplanes and various modes of transportation usually run on a form of fossil fuel such as gasoline or diesel fuel. The foods and consumer products that we buy and use daily are produced in factories that run on various sources of energy. Every aspect of our modern life has been fueled through the transformation of natural resources into disposable forms of energy. And as the global population continues to grow and energy consumption grows alongside, accelerated by economic growth, global marketed energy consumption is projected to grow by over 200% in comparison to 1990 standards according to estimates by the International Energy Agency (IEA), as shown in Figure 1.

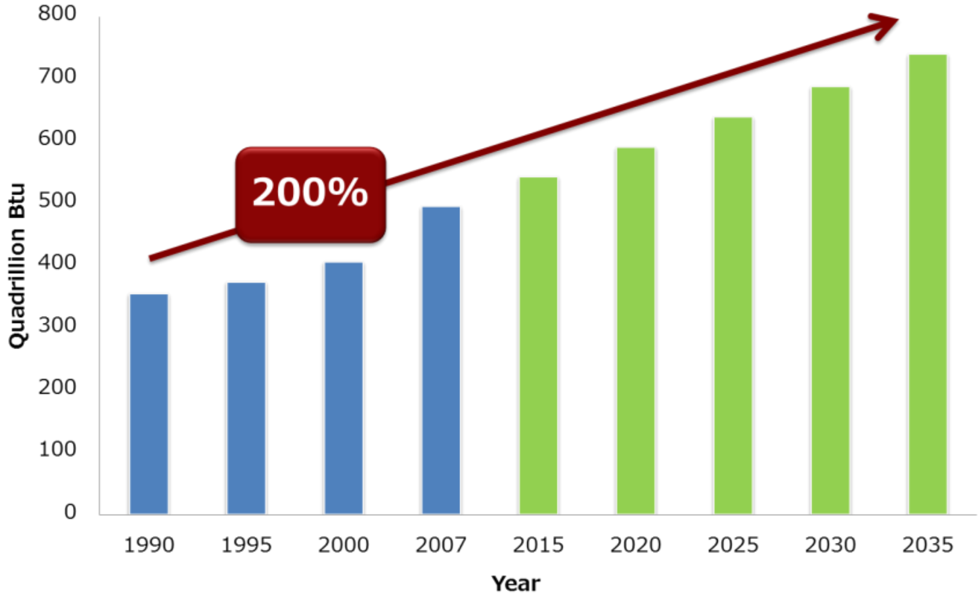


Figure 1 Global Marketed Energy Consumption 1990-2035

(Figure drawn by author based on data from IEA 2010)

Although energy consumption has been on a steady rise since 1990 and even before that, there is an important change in the composition of this growth. The older decades had been characterized by energy growth in the developed nations of the world such as the United States, Western Europe and Japan. The recent growth, on the other hand, can be predominantly ascribed to growth outside of the Organization for Economic Co-Operation and Development (OECD), especially in non-OECD Eurasia.

Energy consumption in “emerged” economies such as China and India grow rapidly and other “emerging” countries follow in their footsteps. Growth in non-OECD Eurasian energy consumption is forecasted at 600% in comparison with 1990 standards (IEA 2010). This accounts for nearly two-thirds of the growth in global energy consumption from 1990 to 2035, and has acted as one of the causes for increased geopolitical tension in the region.

1.2 The Importance of Natural Gas

Within this unprecedented growth in global energy consumption, natural gas is gaining increased attention as a considerably "cleaner" source of energy in terms of carbon emission compared to coal and oil. As shown in Figure 2 below, brown coal produces 950kg of carbon dioxide per megawatt of energy, and furnace fuel oil produces 650kg per megawatt, while natural gas only produces 380kg per megawatt. This is only one-third of coal and half of oil, and given the abovementioned global growth in energy consumption, these significant differences in carbon dioxide emissions will make an enormous difference in the global carbon dioxide emission, and this is precisely one of the reasons that natural gas has been viewed as a candidate for replacing nuclear energy as an interim source of energy until renewable energy becomes truly economically viable.

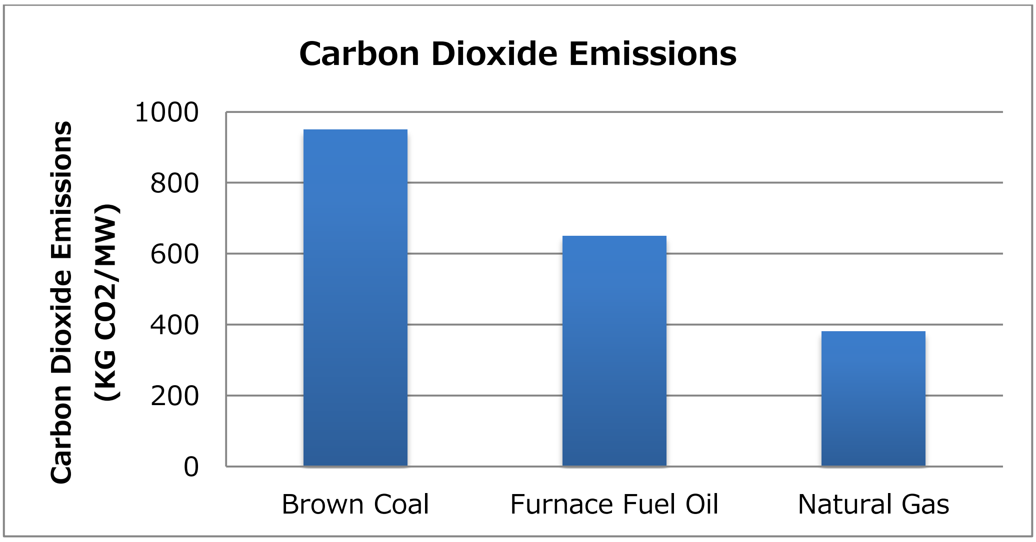


Figure 2 Volume of Carbon Dioxide Emissions, KG CO2 / MW

(Figure drawn by author based on Gazprom 2010)

These obvious advantages of natural gas in comparison to coal, oil and nuclear energy has pushed it into the position as the second largest source of energy for power generation (22% of primary energy source consumption in power generation), as shown in Figure 3 below.

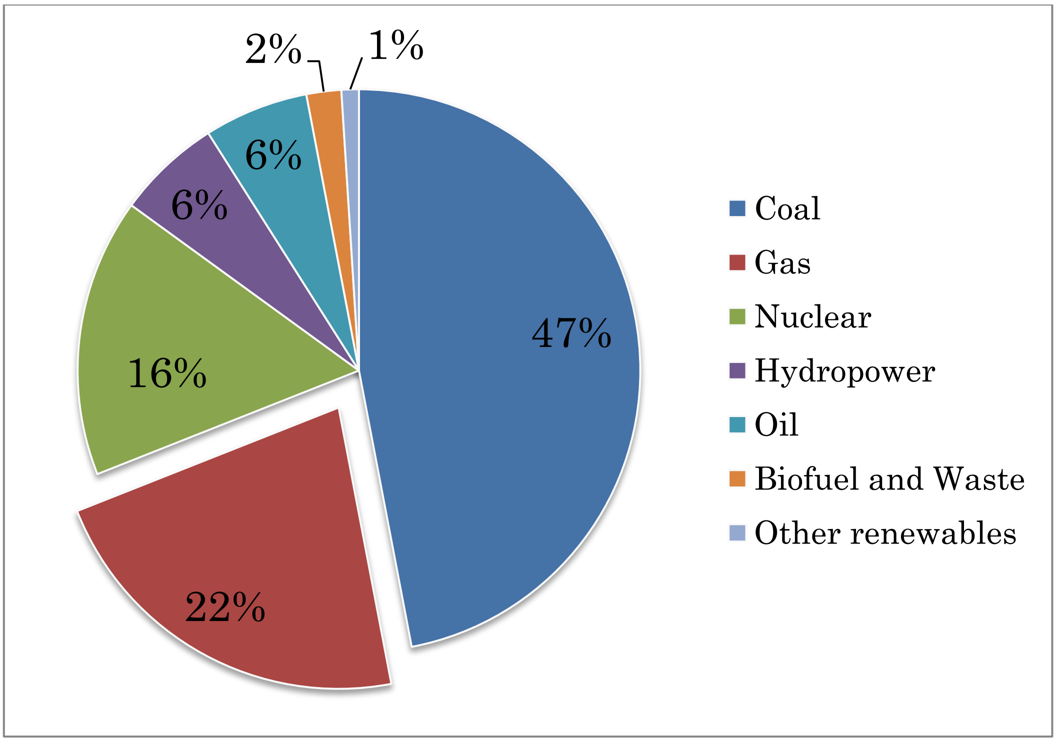


Figure 3 Primary Energy Sources in Power Generation

(Figure Drawn by author based on Gazprom 2010)

Two remarkable events have also contributed in accelerating natural gas's ascension to the status as one of the most crucial sources of energy in the coming decades. The tragic earthquake and tsunami in Eastern Japan on March 11th, 2011 and consequent energy security aftershocks of the Fukushima Nuclear Disaster has led to a gush of anti-nuclear sentiments and never-before-seen demonstrations not only in Japan but elsewhere in the world, and nuclear energy policies have shifted accordingly. Countries such as Switzerland and Germany have made political decisions that are significant steps toward a non-nuclear future. Even if many countries would not be able to decrease the number of nuclear power plants in the immediate future, the political hurdle for new construction of nuclear power plants has become higher than ever before.

Given the two facts that (1) energy consumption continues to grow in the world and that (2) nuclear power, which had been the candidate for interim energy until renewable energy became viable, has encountered a giant hurdle, many countries will be forced to look at a non-nuclear source for their growing energy demand. Natural gas is one “natural” option.

The other event that will further magnify the importance of natural gas is the evolution in technology that has led to the so-called “Shale Gas Revolution”. Shale gas is an “unconventional” form of natural gas, formed from being trapped within specific formations in the geologic stratum called “shale formations”. According to the United States Energy Information Administration (EIA), conventional gas accumulations “occur when gas migrates from gas rich shale into an overlying sandstone formation, and then becomes trapped by an overlying impermeable formation, called the seal.”(EIA 2012). In other words, although shale gas is referred to as “nonconventional”, the gas rich shale is actually where “conventional” sources of natural gas originate.

The shale gas revolution is expected to continue, already evident in the sharp drop in domestic natural gas prices in the United States where the technology is adopted most rapidly. It is estimated that at current production rates, the total natural gas reserves in the United States is equal to over a century's supply of domestic gas. Other countries such as Russia, China, Mexico and Argentina have also been predicted to have significantly large natural gas reserves in unconventional forms. Global gas production could increase by 50% between 2010 and 2035, with unconventional sources supplying two-thirds of the growth. Although the focus of this thesis is conventional natural gas exported through pipelines, the unconventional gas revolution is noteworthy because it would lead to an increase in consumption of natural gas, which would raise countries' dependence on natural gas as a source of energy and thus the importance of it, both in conventional and unconventional form. Therefore, it would be appropriate to forecast that the importance of natural gas will only increase in the coming years.

1.3 The Two Causes of Complexity in Natural Gas

Not only is natural gas one of the most important sources of energy in the foreseeable future, it is arguably one of the most geopolitical and geostrategic, thus making it the subject of this thesis. There are two main reasons as to why natural gas is characterized by geopolitical and geostrategic complexity: its distribution is geographically uneven, and it is difficult to store and transport.

As shown in Figure 4, it has been estimated since 1991 that over 70% of proven global natural gas reserves were located in the Middle East and the former Soviet Union. Although proved reserves have grown by over 58% from 1991 to 2011, the proportion that these two regions govern has actually increased, from 74.4% in 1991 to 76.2% in 2011 (BP 2012). Although the abovementioned Shale Gas Revolution may lead to a shift in the proportion of natural gas reserves, it is an unmovable fact that the Middle Eastern and former Soviet Union have been the dominant producers of low-production cost natural gas in the past decades and perhaps another decade or so to come.

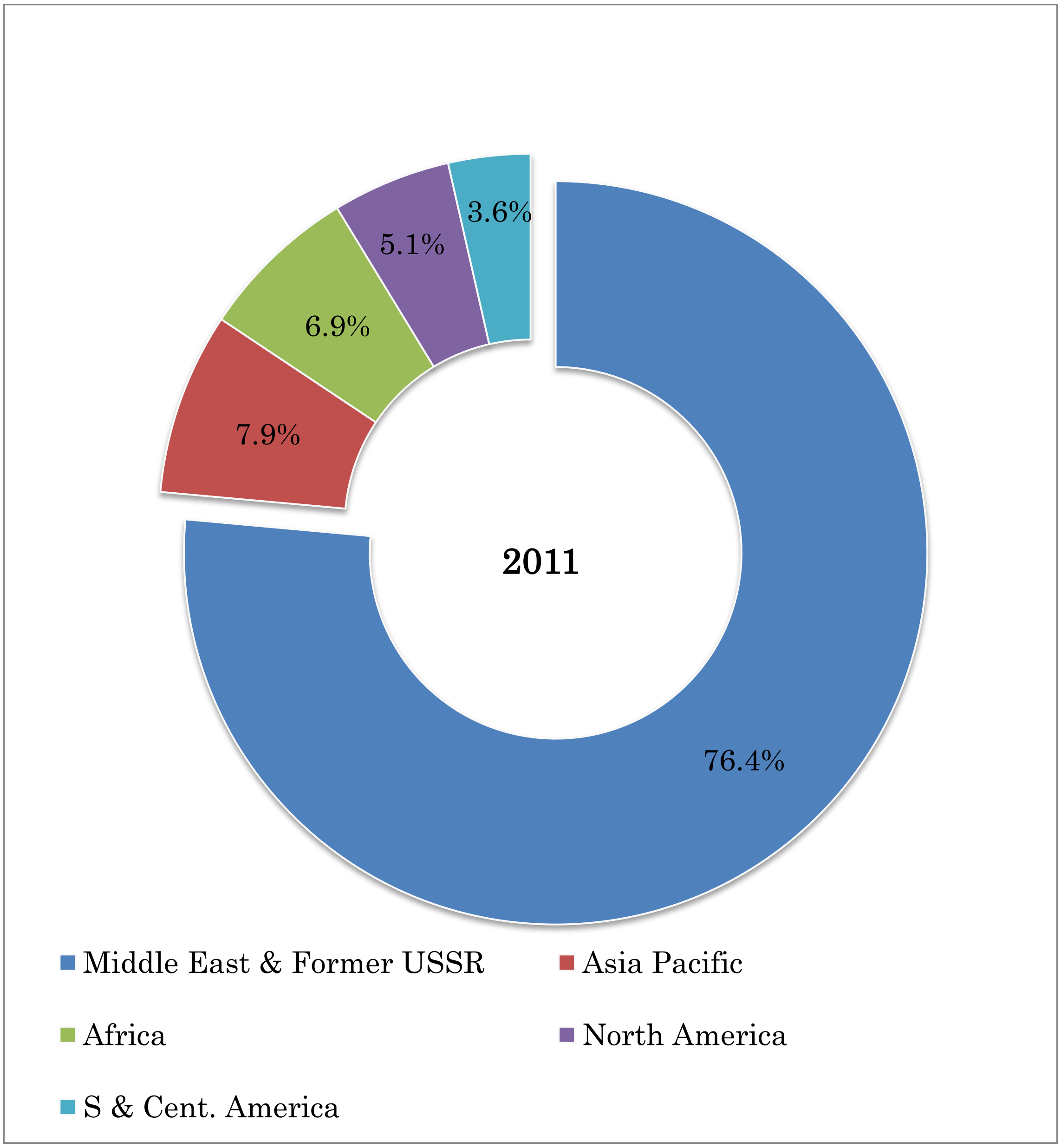


Figure 4 Distribution of Proved Natural Gas Reserves in 1991, 2001 and 2011

(Figure Drawn by Author based on BP 2012)

Yet, geographically uneven distribution of reserves alone does not explain why natural gas is arguably “the most” geopolitical of natural resources, because the global distribution of crude oil is similarly uneven. Exploration into this question leads to the second reason, which is the difficulty of storage and transportation.

Natural gas, by definition, exists in the form of gas, while other sources of fossil fuel exist in other states of matter. For example, crude oil exists in the form of liquid and coal exists in the form of solids. Therefore, while oil may be stored in tanks and coal can be stored anywhere, natural gas, once excavated, would dissipate into the atmosphere unless properly stored or transported. When storing natural gas, it must first be liquefied into Liquefied Natural Gas (LNG) in order to store in volume. This is extra cost that oil, which can be naturally stored in the form of liquid, or coal, stored as a solid, does not incur. Therefore, in order to eliminate such extra costs, it is ideal that natural gas is consumed without going through the liquefaction process. In other words, natural gas should be excavated and sent directly to the consumers in the gas state for better profitability. And this is precisely the reason why natural gas is often transported through natural gas pipelines that spread across continents as transboundary infrastructure, as in the title of this thesis.

Combining the two reasons explained above regarding the globally uneven distribution of natural gas reserves and the difficulty of its storage and transportation, the following statement can be reached: global natural gas trade is characterized by a small number of gas producers, mostly in the Middle East and former Soviet Union, to excavate natural gas and preferably transport it in the form of gas rather than liquids or solids, across borders through natural gas pipelines to consumers around the continent and around the globe that continue to grow in terms of energy demand, and especially natural gas as the relatively cleaner interim source of energy.

1.4 The Hold-up Problem and the Geopolitics of Natural Gas Pipelines

Geopolitics is a broad concept that has various definitions, one of such being the "study of reciprocal relations between geography, politics and power and also the interactions arising from combination of them with each other" (Hafeznia 2006). Much of international politics may be attributed in some way or another to the concept of geopolitics, but this thesis declares that natural gas pipelines are among the most geopolitical of infrastructures, and natural gas among the most geopolitical of resources, for the reasons states in the previous section. When Friedrich Ratzel, one of the founding fathers of geopolitics and a controversial figure due to the association of German "Geopolitiks" with Nazism, first emphasized the importance of mobility, he forecasted that the move from sea transport to land transport would govern the geopolitical power of nations. Sir Halford Mackinder, another renown founding father of geopolitics, also argued that railroads had removed the invulnerability of the Heartland (center of the Eurasian continent) to land invasion. Transboundary infrastructure had been one of the most crucial components of classical geopolitics.

Much of the rationale behind classical geopolitics has vanished in present day because of the development of air transportation. Although the ability for nations to deploy large quantities of supplies through land transportation is still of importance, air and sea transportation in combination with a freer market has alleviated a large portion of the geopolitical stress that existed in the classical days. Why then, would natural gas be deemed a classically "geopolitical" subject?

Natural gas is transported either through extensive networks of transboundary natural gas pipelines or in the form of LNG, usually shipped on massive LNG tankers.

Although advancement in liquefaction and gasification technology has led to rapid growth in the LNG market, the predominant method of natural gas transportation is still through trans-boundary natural gas pipelines due to the abovementioned reasons such as the cost of liquefaction and regasification. As a result, the proportion of natural gas traded in the form of LNG is still at about 27% of the total trade of natural gas in the world, as shown in Figure 5 below.

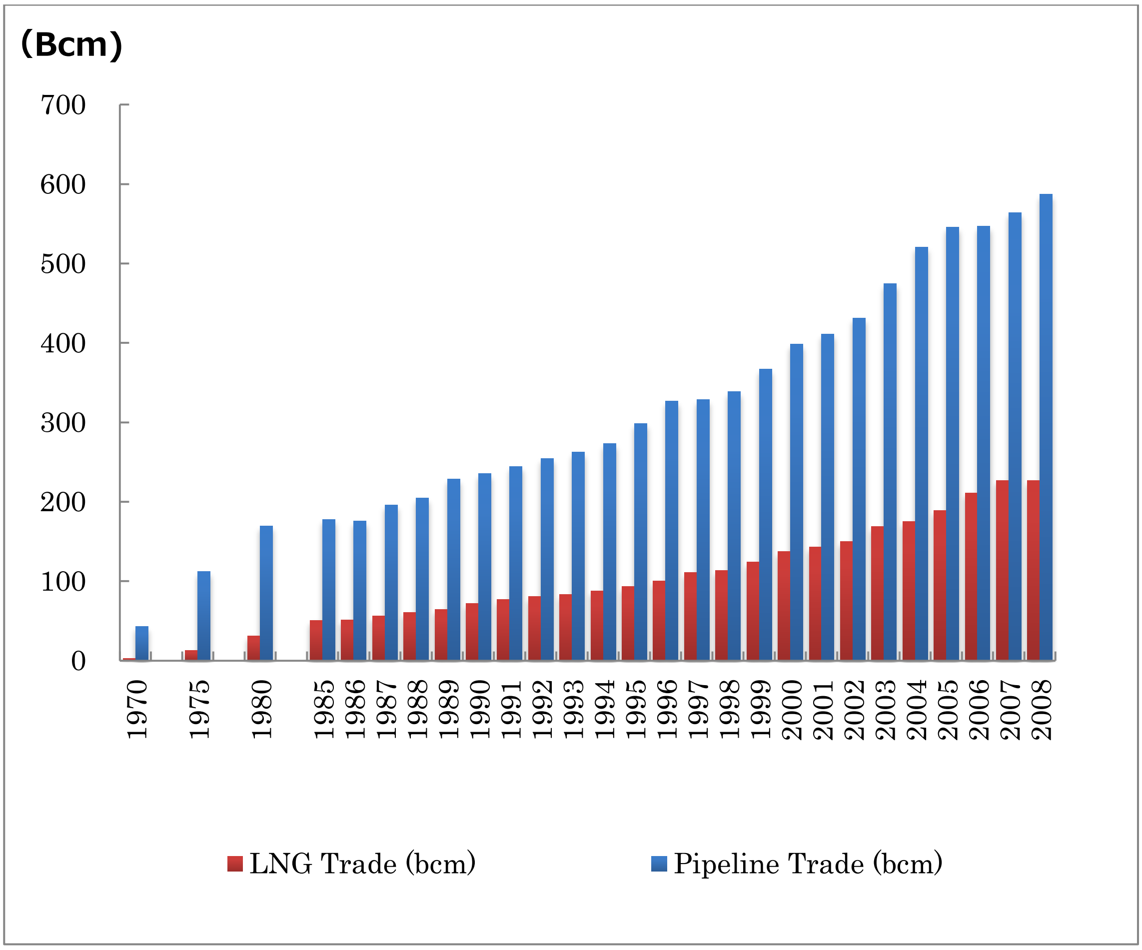


Figure 5 Natural Gas Transportation by Mode of Transportation

(Graph drawn by Author based on data from the Japanese Agency of Natural Resources and Energy)

The characteristic of natural gas pipelines that adds to the geopolitical complexity of natural gas trade is its high level of specificity as an infrastructure. In other words, the only type of good that natural gas pipelines can transport is obviously natural gas. This is significantly different from roads, railways, planes and ships that can, with little modification, transport a multitude of goods. And precisely for this specificity, natural gas pipelines are vulnerable to classical economic issues such as the hold-up problem, which may occur between producers and transit countries, or producers and consumers.

The hold-up problem is a classical problem in economics where two or more players, such as exporters, intermediaries (e.g. transit player) and importers, may benefit from cooperating (e.g. building a pipeline between the two players), but unilaterally or multilaterally refrain from cooperating due to concerns that the consequent shift in bargaining power may be of disadvantage to oneself. For example, if a natural gas producer invests in pipelines to export natural gas to a consumer, the producer must collect the usually large investments through profits made in the natural gas trade. If there are two producers (A and B, for example) and only one consumer in the market, and producer A has recently invested in a pipeline to the consumer, the consumer can threaten to switch to producer B for natural gas, which would prevent producer A from collecting its initial investment. If producer B is able to meet the consumer’s demand, this is a highly credible threat of great concern for producer A.

On the other hand, if the infrastructure that producer A invested in was not specific to a single good, as in the case of roads or railways, producer A can decide to trade a different type of good through the same road or railway. These alternative goods act as an outside option for the producer/initial investor, but in the case of natural gas pipelines, such alternative trade strategies do not exist, and thus outside options are nonexistent. Therefore, committing to an initial investment may weaken the investor's bargaining power and lead to the hold-up problem.

Further adding to the complexity is the existence of the so-called "transit countries". Transit countries in the context of natural gas are countries that are located along the natural gas pipelines, between the producing country and consuming market. The classical example is Ukraine and Belarus as transit countries between Russia, the producer, and Western Europe, the consuming market. Transit players are often consumers themselves, but also at times have sovereign control over the portion of the pipeline that crosses through their boundaries. Therefore, the lineup of countries along the natural gas pipeline has a significant effect on the stability and well-being of natural gas trade.

For these reasons, natural gas pipelines are clearly an infrastructure that can be characterized as a condensation of classical geopolitics. Both geography and politics affect pipeline routes, and both domestic and international politics that arise from natural gas trade affect power among countries involved in the trade, further exerting influence on the design and route of future natural gas pipelines and plans. These are precisely the "reciprocal relations" that Hafeznia (2006) places at the center of the definition of geopolitics. Natural gas pipelines are geopolitical in nature.

2 Research Objective and Methodological Approach

2.1 Research Objective

If natural gas is indeed a condensation of classical geopolitics, then natural gas can easily become a source of instability among countries that are involved in its trade. The Russian-Ukrainian Gas Disputes that have been a grave concern for natural gas importing countries in Western Europe are a prime example in which the transit country had put its weight behind its strategic position and thus led to consequences such as a serious shortage of gas in the blistering cold winters of Europe.

Russia, Ukraine and Belarus had all formerly been a part of the Soviet Union, and even after its dissolution, bilateral relations had been mostly amiable. But unfortunately, the international trade of resources and the consequent energy geopolitics has the power to turn such family-like ties into one of bargaining and tactics. When Russia demanded Ukraine to pay a higher fee for the gas that they purchased, Ukraine accused the Russian leadership that this raising of prices was a "'punishment' for the December 2004 election of Viktor Yushchenko as Ukraine's president over the Moscow-supported candidate, Viktor Yanukovich" (Sokov 2006).

What then, would be the consequences of a geopolitical dispute over natural gas trade among nations like India and Pakistan? What about in East Asia, where there are rumors that Russia's state-owned gas company Gazprom hopes to build a pipeline that originates in Russia, passes through the People's Republic of China, through the Democratic People's Republic of Korea (North Korea), the Republic of Korea (South Korea), and then finally to Japan? If the planners and decision makers of these pipeline plans do not consider with sheer meticulousness the myriad of geopolitical conflicts that may be instigated, the natural gas pipelines may also transport and disperse a fume of geopolitical instability. How then, can the impact that natural gas pipelines and pipeline plans may have on the relationship among countries involved in the trade of this increasingly important resource be modeled, analyzed and applied? With this question in mind, this research aimed to achieve the following objectives:

① In order to unravel the strategic relationship among countries involved in the trade of natural gas, a model (Network Game) and solution concept (Link-based Flexible Network Allocation Rule) that has not yet been applied to the subject was applied, and comparisons were made with existing literature in order to find areas in which the newly applied model can improve the versatility in modeling so as to better reflect the reality of the pipeline network

② In order to gain insight into the geopolitical interactions that existing or planned transboundary infrastructure may instigate, analyses were conducted for several cases, and the strategic impact that these pipeline plans would have on the power structure (i.e. Relative Bargaining Power) of the players was explored. Results were compared with existing literature in order to find evidence, both from a qualitative and quantitative perspective, that the results from the newly proposed model can better explain the events that happened in reality, especially in relation to the bilateral natural gas price negotiations between Russia and the transit countries (i.e. Ukraine and Belarus) relative to Western Europe.

③ In order to lay foundation for forecasts and recommendations that may be of assistance in mitigating such political power games, the cases were further explored in order to identify possible causes of the crises that the natural gas trading countries in Europe had experienced.

2.2 Methodological Approach

The methodological approach employed in this thesis took the form of a four-step process.

First, a network game model was built for the trade of natural gas, with special emphasis on allocation rules that might serve as a way to measure the relative power of players (*i.e.* countries) involved in the trade of natural gas. As mentioned in Chapter 1, this thesis applied the network game model and employed the Link-based Flexible Network Allocation Rule proposed by Jackson (2005) as the solution concept by which the relative power of players is estimated, and the relative value allocated to each of the links involved in the pipeline network. Thus, this is referred to as the "Relative Bargaining Power" of the players involved.

Second, a real-word case was selected to apply the model to, and in order to gain insight into the explanatory power of the model, results were compared with the existing literature of Hubert and Ikonnikova (2011), replicating the calibration (details of the calibration are explained in Chapter 7). By checking whether a closely replicated game would yield results that are sufficiently similar to the results of Hubert and Ikonnikova (2011) would provide justification for comparison between the two models. Four different scenarios were compared.

Third, the additional modeling capabilities of the model and solution concept employed in this thesis were utilized in order to design a network that better reflects the reality of the case. Specifically, this thesis took into account the fact that (1) Ukraine and Belarus are not mere transit players but significantly large importers of Russian natural gas and (2) Western Europe is not a mere non-strategic consuming market but a strategic player in the pipeline network.

The fourth and final step was an attempt to find empirical evidence that the results yielded by the model proposed in this thesis is able to better explain the events that have taken place in reality. Specifically, whereas Hubert and Ikonnikova (2011) used explicit gas compensation and gas discount as a means to validate the results of the computation, this thesis took the Nord Stream Pipeline Plan as the case, and searched for signs of changes in Relative Bargaining Power that may have manifested in the outcome of bilateral price negotiations between Russia and the transit countries.

2.3 Structure of the Thesis

The structure of the thesis is as explained below.

Chapter 1 explains the reasons why natural gas, among the various natural resources, is an especially geopolitical and geostrategic subject of great importance.

Chapter 2 introduces the research objectives, methodological approach and the structure of the thesis.

Chapter 3 explores existing literature from two perspectives. The first is from the theoretical perspective, with Game Theory and Network Games at its foundation. The second is from a Geopolitical perspective, especially in relation to Classical Geopolitics and energy.

Chapter 4 describes in detail the setup and structure of Network Games, and the definition of Value Functions.

Chapter 5 covers the key events in the history of natural gas trade in the case that this thesis analyzed: from the former Russian Empire, former Soviet Union and to the present day gas trade on the Eurasian Continent.

Chapter 6 examines the details of the main case that this thesis analyzed (Nord Stream Pipeline) and the years since its original inception in 1997.

Chapter 7 explains the two game setups that were to be compared in order to gain insight into the versatility and explanatory power of the proposed model. A game is set up based partly on and closely replicating the calibration in existing work by Hubert and Ikonnikova (2011), but uses the Network Game and Link-Based Flexible Network Allocation Rule. Then, another game setup that is unique to this thesis, treating Ukraine and Belarus as importers as well as transit countries and Western Europe was an additional strategic player, are explained.

Chapter 8 presents the results and interpretation of the four scenarios that are analyzed in this research.

Chapter 9 introduces quantitative and qualitative approaches for finding empirical evidence that the results of this research better explain the events that happened in reality.

Chapter 10 concludes the thesis by commenting on the possible causes of the tension that existed among the natural gas trading countries especially in the 21st century, and makes policy recommendations that would mitigate the risk of tension over natural gas pipeline networks.

Chapter 11 provides final comments on the implications that the results of this thesis may have on other cases of natural gas geopolitics, and lists possible areas for further work in this context.

3 Previous Literature

There are two lines of previous literature that are relevant to this thesis: the theoretical model (*i.e.* game theory and network theory) and the study of natural gas pipelines, especially in the context of geopolitics. Figure 6 below shows a map of the schools of thought that are relevant to this thesis.

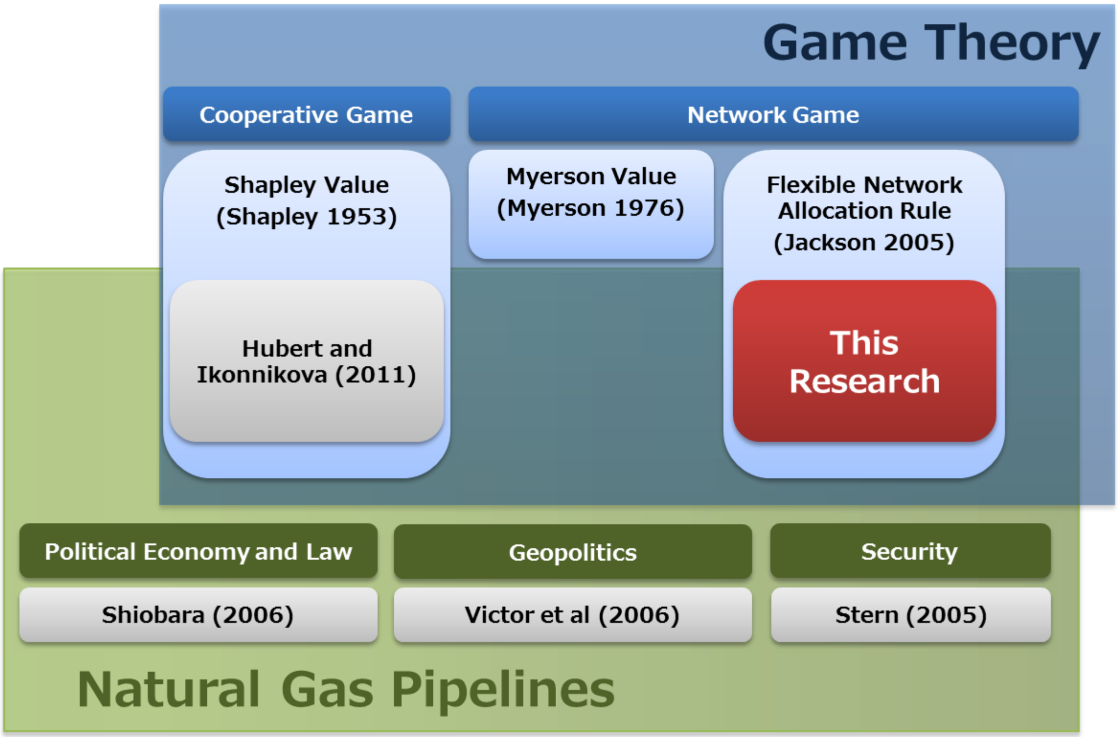


Figure 6 Position of Research within Schools of Thought

3.1 Theoretical Models

Game Theory

As abovementioned, this research has its theoretical foundation in the fields of Game Theory and Network Theory. Game Theory is "the study of mathematical models of conflict and cooperation between intelligent rational decision-makers" (Myerson 1991). And Game Theory is again separated into two branches, Non-Cooperative Games and Cooperative Games. A game is Non-Cooperative if the players involved are not allowed to enter into a cooperative agreement (e.g. coalition) so that "the selection of actions or decisions is done collectively and with full trust, so that all players would benefit to the extent possible, and no inefficiency would arise" (Basar 2010). On the other hand, if the players are allowed to cooperate amongst themselves to form coalitions, then that game is said to be a *Cooperative Game*.

Cooperative and Non-Cooperative Game

Natural gas pipelines have been extensively studied and analyzed using both types of games. For example, von Hirschhausen, et al. (2004) examined "the options of transporting Russian gas to Western Europe" by using both a cooperative and non-cooperative model. The paper then "developed a model of different strategies of Russia and Ukraine, and derived the analytical solution for Russian gas exports to Western Europe, prices, and the expected profits for the players" (von Hirschhausen, et al. 2004). As evident in this work, the benefit of using game theory is that the countries involved in the trade of natural gas can be treated as the players of a game theoretical model, and variables such as prices and expected profits of the players can be used to define the necessary numerical setups of the model. And through calculations of such models, one is able to obtain quantitative insight into the politics and economics of natural gas pipelines. Von Hirschhausen, et al. (2004) was able to forecast results such as the loss that Ukraine suffers by Belarus's entry, Russia's increased profits and incentive to expand its gas transit capacity through Belarus, and lower prices for Western European importers in exchange for higher dependence on Russia.

The work by von Hirschhausen, et al. (2004) is a classical application of game theory, both non-cooperative and cooperative, to natural gas trade. Their work makes interesting forecasts about the gains and losses that the countries would experience as a result of changes in their strategies, but does not explicitly lay out a way to analyze how the intrinsic Relative Bargaining Power is affected by strategy changes. In other words, von Hirschhausen, et al. (2004) forecasts the economic gains and losses, but does not translate this into political gains and losses, which is clearly a key component in this context.

The work by Abada et al (2012) presents a dynamic Generalized Nash-Cournot model to describe how the natural gas markets have evolved. Their work has forecasted natural gas market conditions up until year 2030, with the market power and demand representations taken into account.

The work by Galizzi (2006) suggests a bargaining model that is based on a bilateral Rubinstein negotiation, in which bargaining takes place between a buyer and two sellers. The work is distinct in that it models price formation both in a fixed network as well as an endogenously formed buyers-sellers network. Because the modeling of endogenous network formation is challenging in the context of natural gas pipelines, extensions of Galizzi (2006) may provide insight into what networks may actually form under given conditions.

Cooperative Game with Relative Shapley Value

Hubert and Ikonnikova (2011) is a representative work that treats the outcomes of a cooperative game (*i.e.* Shapley Value) as the "Relative Shapely Value" of the countries involved in natural gas trade rather than purely economic benefits and losses. With this, the outcome of the Cooperative Game is effectively treated as the implicit political gains and losses that the changes in pipeline structure incur, rather than the explicit economic gains and losses. This approach and interpretation is appropriate for the trade of natural gas because a change in strategy or change in pipeline structure does not necessarily translate directly into economic profits and losses of the players involved, largely due to the fact that natural gas is traded amongst these countries in long-term contracts, and because various political and geopolitical interactions may play a role in determining the actual outcome.

Therefore, treating changes in Relative Shapley Value as a mixture of both economic and political benefits and losses leaves flexibility in the interpretation of the results. The outcome may have manifested partially as economic gains, and partially as political compromises. "Relative Shapley Value", or in this thesis "Relative Bargaining Power", is able to capture this entirety.

Hubert and Ikonnikova (2011) was only able to model the cases in which Russia is the sole producer/exporter of natural gas, Ukraine and Belarus are pure transit countries rather than themselves being importers of natural gas, and Western Europe is not a strategic decision-making player in the game. These assumptions limit the accurate modeling of reality in the trade of natural gas in the Eurasian context, and bring about serious limitations in the scope of analysis. Thus, this thesis argues that a

Network Game approach utilizing the Flexible Network Allocation Rule is a more versatile approach in modeling this context, as it can take into account the conditions that Hubert and Ikonnikova (2011) had to inevitably disregard. Direct comparisons with Hubert and Ikonnikova (2011) are made in the following chapter, so here this thesis presents a general discussion regarding the Characteristic Function Form, Partition Function Form and the Network Game.

Previous literature such Hubert and Ikonnikova (2011) use the Characteristic Function Form in defining the game played amongst countries involved in the trade of natural gas. The Characteristic Function Form is defined in the following manner.

Characteristic Function Form

Let $n \geq 2$ denote the number of players in the game, and let N denote the set of players $N = \{1,2,\dots,n\}$. A coalition S is defined as $S \subseteq N$, and the set of all coalitions is denoted by 2^N. By convention, the "empty set" is defined as $\emptyset$, and the set N in which all players join is the grand coalition. Therefore, a game in the Characteristic Function Form in which there are two players, four coalition may be defined: $\{\emptyset, \{1\}, \{2\}, N\}$. In a game where there are three players, eight coalitions are defined: $\{\emptyset, \{1\}, \{2\}, \{3\}, \{1,2\}, \{1,3\}, \{2,3\}, N\}$. For a game with n players, the set of coalitions has 2^N elements.

The coalitional form of an *n*-person game is given by the pair (N, v), where $N = \{1,2,\dots,n\}$ is the set of players and v is the Characteristic Function of the game, defined on the set 2^N of all coalitions and satisfying the following two conditions:

(i) $v(\emptyset) = 0$

(ii) if S and T are disjoint coalitions $S \cap \mathrm{T} = \emptyset$, then

$$v(S) + v(T) \leq v(S \cup T)$$

The second condition above is known as Superadditivity.

Shapley Value

A number of solution concepts exist for games in the Characteristic Function Form, such as the Core, the Nucleolus and the Shapley Value. Hubert and Ikonnikova (2011) uses all of these solution concepts, but the strongest emphasis is on the Shapley Value, or “Relative Shapley Value” to be more accurate.

The Shapley Value is an imputation, which is a function defined as below.

$$\Phi_i(v) = \sum_{S \in N \setminus \{\mathrm{i}\}} (v(S \cup \{i\} - v(S)) \left(\frac{\#S!(n - \#S - 1)!}{n!}\right) \quad (1)$$

An imputation indicates “how much of the value generated by the full society is allocated to each player”, and it is “generally presumed that the grand coalition of the full society generates the maximum possible value” (Jackson 2008). Much of the Cooperative Game literature makes use of the Shapley Value as a solution concept that “takes into account the relative marginal contributions of the players toward productive value” (Jackson 2008), in order to compute the “fair” allocation for each player involved in the game. In other words, players receive an allocation based on their contribution to the value of the coalition.

While the Characteristic Function Form is a clear and computable way to model the different values that coalitions may yield as well as the contributions of each player within such coalition, and the Shapely Value is a logical explanation for how value should be allocated within such coalitions, the Characteristic Function Form Game fails to account for the externalities that may exist. For example, if there are four players defined as $N = \{1,2,3,4\}$, a coalition $\{1,2\}$ may be formed between player 1 and 2. In the Characteristic Function Form, the value function $v(1,2)$ yields a unique value. But intrinsically, one would know that the value of $v(1,2)$ would be affected in the case where the other two players, 3 and 4, would form a coalition amongst themselves rather than to stay singleton. Yet, because of the concise nature of Characteristic Functions in assigning a unique value to a specific coalition, these externalities cannot be taken into consideration.

Partition Function Form

Of the attempts to overcome this shortcoming of Characteristic Function Form Games, one well-known approach is the use of games in Partition Function Form, devised by Thrall and Lucas (1963). A Partition Function "assigns a worth to each pair consisting of a coalition and a coalition structure which contains that coalition. Such pairs are called embedded coalitions. Games in partition function form are considered as a useful extension of classical Transferrable Utility Games, since they well capture the externalities in an economy" (Grabisch and Funaki 2008). In other words, the Partition Function Form Game overcomes the issue of externalities by assigning a value to the Partition Function Form, which is a Function that defines a unique value for a coalition and all of the possible externalities that may occur outside of this coalition. Using the previous 4-player example, the Partition Function is able to assign a value $v\{(1,2),(3),(4)\}$ to the case in which players 3 and 4 remain singleton, and a separate value $v\{(1,2),(3,4)\}$ to the case in which the "external players" (from the perspective of coalition (1,2)) also form a coalition, (3,4).

The power of the Partition Function in capturing externalities is essential for the analysis of natural gas pipelines. For example, if Russia and Ukraine are involved in a pipeline that exports natural gas to the Western European market, the value of this coalition may be affected greatly by externalities such as the Western European market being connected to other sources of gas (e.g. Iraq, Iran, Turkmenistan). Characteristic Functions fail to model such cases. The advantages that may be brought about in modeling reality through the use of a concept like the Partition Function Form are very clear, but there are still two major issues regarding Partition Function Form Games: difficulty of computation, and the issue of overlapping coalitions.

As abovementioned, the number of elements in a Characteristic Function Form Game is given as 2^N. Therefore, the number of elements in a game with three players is 8, and the number of elements in a game with 5 players is 32. With the Partition Function Form, this number skyrockets as the number of players increases. The total number of elements in a Partition Function Form Game is given by $\sum_{k=1}^{n} kS_{n,k} + 1$ where $S_{n,k}$ is the Stirling number of second kind. The number of elements for games of the Partition Function Form from a case with one player to a case with eight players is given in the Table 1 below.

Table 1. Number of Elements in Partition Function Form Games

(based on Grabisch and Funaki 2008)

n	1	2	3	4	5	6	7	8
Number of Elements	2	4	11	38	152	675	3264	17008

A game with eight players involves 17,008 elements, and a separate Partition Function must be defined for each. Although this does not immediately lead to the conclusion that Partition Function Form Games are incomputable, the necessity to assign a value to each of these elements puts a limitation on practical application.

The other shortcoming is the issue regarding overlapping coalitions. In the previous example where players 1 and 2 join in a coalition and players 3 and 4 decide whether to form a coalition amongst them or not, the case in which player 1 forms a coalition with player 2, and another coalition with player 3, is omitted. In other words, as soon as player 1 chooses to form a coalition with player 2, player 1 loses the option of forming a separate coalition with player 3. A real example is used below to illustrate this issue in more detail.

The classical example of the geopolitics of natural gas that is dealt with in this thesis is the construction of the Nord Stream Pipeline, which connects the Western European gas market to the Russian gas sources with a direct underwater pipeline that passes through the Baltic Sea. Because Russia and Western Europe are already connected through the onshore pipelines that pass through Ukraine and Belarus, it can be interpreted that Russia and Ukraine are involved in a coalition $\{Russia, Ukraine\}$

and coalition $\{Russia, Belarus\}$ that connect the Russian gas supplies with Western Europe. The value of these two onshore coalitions may be greatly affected by the obvious "bypass" function that the Nord Stream pipeline is designed to play. Because Russia is already involved in a coalition with Ukraine and Belarus, the Characteristic Function Form Game is not able to bring Nord Stream pipeline into the coalition. The Partition Function Form Game also fails to do this because the additional modeling power that Partition Function Form Games brings is the consideration of externalities. In this case, Russia is already an internal player that is involved in the coalition, and the formation of the Nord Stream pipeline would thus be an "internality" rather than an externality. A case in which Russia is simultaneously involved in a coalition with $\{Russia, Ukraine, Belarus\}$ and $\{Russia, Western\ Europe\}$ would have to be considered. Such overlapping coalitions are not taken into consideration in games of the Partition Function Form, and given the already complex computations that arise from the numerous elements of a Partition Function Form Game, considering these overlaps would add orders of power more complexity to the definition of Partition Functions. Thus, the class of games known gas Network Games, which defines values for the structure of networks rather than to Coalitions or Partitions, is considered in this thesis.

Communication Game

Communication games are a subclass of the cooperative game genus that was originally devised by Myerson (1991). Myerson first defines a convex Transferrable Utility game $(N, v) \in V(N)$ where N is the set of players, v is the characteristic function, (N, v) is the Transferrable Utility Game and $V(N)$ is the set of all such games on N. The Transferrable Utility cooperative game is then augmented by a network $g \in G(N)$ that describes the possible communication lines between players. Given that $\Pi(\mathrm{S},\mathrm{g}|\mathrm{S})$ is the partition of S generated by the components of g restricted to S, the Communication Game (N,v,g) induces a cooperative game $(N,\hat{v}_g)$ such that

$$\hat{v}_g(S) = \sum_{C\in\Pi(\mathrm{S},\mathrm{g}|\mathrm{S})} v(C) \tag{2}$$

Further, Myerson (1991) defined a Shapley Value-like extension for communication games, later coined as the Myerson Value. The Myerson Value for a communication game (N,v,g) is given with the following definition.

$$\Psi^{MV}(v,g) = \Phi^{SV}(\hat{v}_g) \tag{3}$$

The Communication Game and standard Cooperative Games are interchangeable in a sense. "Although one can view a communication game as a specific form of a cooperative game, the converse is also a reasonable viewpoint. In the case where g is the complete network, a communication game reduces to a cooperative game in that $\hat{v}_g = v$" (Jackson 2008). In other words, the links within a Communication Game assist in defining the restrictions that may apply in the actual value-inducing coalition structures. For example, if players 1 and 4 are not connected in the network as in the Figure 7, then a coalition between players 1 and 4, or any coalition between any player and player 4 would yield a value of zero. Players 1, 2 and 3 are unable to "communicate" with player 4, and any coalition that is unable to communicate through a link in the network structure yields an additional value of zero.

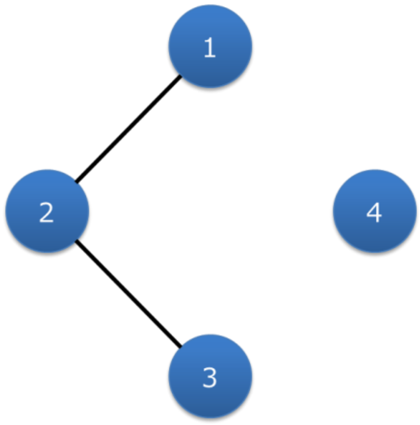


Figure 7 Communication Game Structure (Link 12, 23)

In the example below (Figure 8), there is now a link between players 1 and 4. Therefore, a coalition that involves players 1 may yield additional value by adding player 4 in the coalition. But again, coalitions would yield additional value by adding player 4 only if player 1 is also involved, because player 1 is the only player that is able to communicate with player 4.

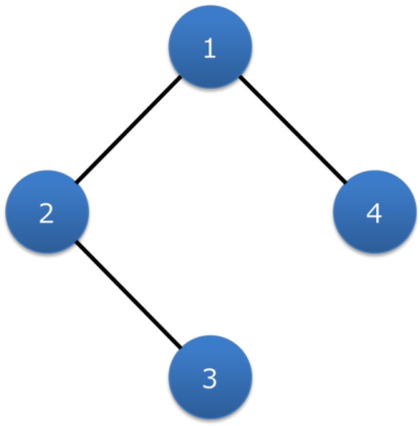


Figure 8 Communication Game Structure (Link 12, 23, 14)

The Myerson Value is an extension of the Shapley Value to networks and successfully "brings networks into the context of cooperative game theory", but "stops short of allowing one to fully analyze the allocation of the values in a network. The difficulty arises because the actual value that a society generates is still based on a characteristic function, and it is mainly the allocation of value that is affected by the network structure, rather than the overall productive possibilities" (Jackson 2008). Thus, in order to unleash the full potential of modeling games in a Network Game Model, Jackson and Wolinsky proposed the Network Game model that is captured by the value function.

This thesis employed the model devised by Jackson and Wolinsky (1996), and the details will be defined in Chapter 5 along with the solution concept, Link-based Flexible Network Allocation Rule. Network Games are at the frontier of modeling in the Cooperative Game literature, and this thesis is one of the earlier attempts in employing the model in an empirical manner to a case that is appropriate to model as a network, and thus the full potential of the model may be utilized.

3.2 Natural Gas Pipeline Geopolitics

A brief definition of the term *Geopolitics* was introduced in Chapter 1. As noted by Flint (2006), Geopolitics is a "word that conjures up images. In one sense, the word provokes ideas of war, empire, and diplomacy: geopolitics is the practice of states controlling and competing for territory. There is another sense by which I mean geopolitics creates images: geopolitics, in theory, language and practice, classifies swathes of territory and masses of people"

Existing work on the subject of natural gas trade include that of Jaffe and Hayes (2006), which provides an extensive overview of natural gas trade around the world, the geopolitical and strategic interaction among countries involved in natural gas trade. Shiobara (2007) introduces various analytic perspectives on the subject, such as the issue of natural monopolies that emerges from pipelines, bypassing of particular countries, the planning of pipeline routes, transit fees and account settlement, externalities generated by technological innovation, and legal restrictions that try to control the strategic aspect of natural gas trade.

Some works explore the outside options that natural gas trading countries may have, such as storage capacities, LNG or unconventional sources such as Shale Gas.

The work by Austvik (2004) deals with storage facilities. The work views the risk for disruptions in supplies as a negative externality in imports, and that increased consumption of gas entails positive environmental externalities in comparison to other fossil fuels. Thus, the paper argues that these negative and positive externalities can be balanced out, and that "the EU should continue developing a comprehensive energy strategy including security-of-supply considerations", namely strategic gas reserves at which natural gas can be stored in order to mitigate the risk of sudden supply shortages. The work suggests an outside option with which the importers are able to sustain themselves in the event of a supply shock, but says little about how negative externalities can be avoided.

Medlock et al (2011) provides a thorough analysis of the potential that shale gas has and its implication on security (especially in the American context). The United States is where the so-called "Shale Revolution" is taking place at an unprecedented pace, and such readily abundant source of natural gas may have a detrimental effect on the geopolitics of natural gas in the Eurasian continent. Although there does not exist much work on the effect that the Shale Revolution may have on the Russian natural gas trade, Medlock et al (2011) provides implications into the magnitude of this revolution, which in turn provides an idea as to how much Russia may be affected (e.g. the price of natural gas in the United States has already fallen to levels below domestic Russian prices).

Ikonnikova (2009) presents a two-stage model of the LNG market to compare the incentives to enter long-term contracts and trading on the spot trade market. LNG is one of the most important outside options for countries that are connected to natural gas producers through waters. Ikonnikova (2009) established “conditions for emergence of spot trade depending again on demand uncertainty and capital costs”.

The geopolitics of natural gas is governed mainly by the countries that are involved in its trade through transboundary pipelines, as this thesis analyzes, and factors such as those introduced in this section (*i.e.* LNG, storage facilities, Shale gas) are externalities that may have a strong and significant effect on the geopolitics of natural gas pipelines. Either way, it is of utmost importance to be able to model the geopolitics of natural gas pipelines with as much versatility and explanatory power as possible, so that when the newly emergent externalities are additionally considered, their effects may be estimated based on realistic conditions.

4 Network Game Model

As mentioned in the previous chapters, the first step of this thesis employs the network game approach and the Link-based Flexible Network Allocation Rule, as defined below.

4.1 Network Game

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 under 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 $G = \{g | g \subseteq g^N\}$.

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 $g - ij$.

4.2 Value Function and Utility Function

A value function for network g is a function $v: G \to \mathbb{R}$, and the set of all possible value functions is denoted V. As noted in Jackson (2005), a value function "specifies the total value generated by a given network structure, and is a richer object than a characteristic function of a cooperative game or that induced in a communication game because it allows the value that accrues to depend on the network structure and not only on the coalition of players involved".

For example, in a game that involves three players $N = \{1,2,3\}$, a network game in value function form can assign different values to a network $g_1 = \{12,23,13\}$ in which a link exists between all three players, and a network $g_2 = \{12,23\}$ in which a link does not exist between players 1 and 3, but all three players are indeed involved. A cooperative game in the characteristic function form game would have assigned the same value.

This difference is critical when analyzing the strategic relationship of countries involved in natural gas trade. A model based on characteristic function form would not be able to distinguish between a pipeline network in which the *Nord Stream* pipeline directly connects *Russia* with *Western Europe*, and a network in which *Russia* and *Western Europe* are connected only through the old and problematic pipelines that pass through *Ukraine* and *Belarus*. Hubert and Ikonnikova (2011) successfully modeled various pipeline network scenarios as a cooperative game in characteristic function form by assuming that players are restricted to the role as a transit country (*i.e.* they are not consumers of natural gas). Hubert and Ikonnikova (2011) then defined these players' joining the coalition as either as an addition of a link to the already-existing pipeline structure or an alteration (e.g. upgrade of a pipeline) of the already-existing pipeline network structure.

Value function "may involve both costs and benefits, and thus can be interpreted flexibly" (Jackson 2005). Taking advantage of this flexibility, this thesis defined the value $u: G(N) \rightarrow \mathbb{R}$ for each player based on the links that they are connected to, and defined the value function of a network as the sum of these values.

$$v(g) = \sum_{ij} u_{ij}(g) \tag{4}$$

A network game is a pair(N, v), of a set of players and a value function.

Given a value function v, the monotonic cover $\hat{v}$ is defined by

$$\hat{v} = \max_{g' \subseteq g} v(g') \tag{5}$$

4.3 Link-Based Flexible Network Allocation Rule

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" (Jackson 2005). An allocation rule is a function $Y: G \times V \rightarrow \mathbb{R}^n$ such that $\sum_i Y_i(g, v) = v(g)$ for all v and g.

As mentioned in Chapter 3, Myerson (1991) was the first to define what is now known as the Myerson Value, which is a variation of the Shapley value for communication games. Jackson (2005) criticizes the Myerson Value for the following two reasons:

(1) as being insensitive to the possibility of alternative networks

(2) the notion of equal bargaining power

(3) the notion of component balance

Jackson (2005) alternatively provides two new allocation rules that are based on eliminating the notion of equal bargaining power, and replacing the notion of component balance.

The concept that Jackson (2005) introduces is the 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 $v(g) \geq v(g')$ for all $g' \in G$" (Jackson 2005). Thus, efficient networks are value-maximizing networks.

Jackson (2005) defines two variations of his flexible network allocation rule according to whether one assesses value on a player-by-player basis or on a link-by-link basis. Since players can presumably choose to withhold certain links and not others, the link-by-link allocation, or the *link-based flexible network allocation rule*, is considered a richer concept. Because this thesis is interested in the value of links (*i.e.* pipelines) and the players that control these links, the link-based approach is employed.

An allocation rule Y is link-based if there exists $\psi: V \times G \rightarrow R^{n(n-1)/2}$ such that

$$\sum_{ij \in g^N} \psi_{ij}(g,v) = v(g) \qquad (6)$$

and

$$Y_i(g,v) = \sum_{j \neq i} \frac{\psi_{ij}(g,v)}{2} \qquad (7)$$

Finally, the *link-based flexile allocation rule* is defined as

$$Y_i^{LBFN}(g,v) = \frac{v(g)}{\hat{v}(g^N)} \sum_{j \neq i} \left[\sum_{g \in g^N - ij} \frac{1}{2} (\hat{v}(g+ij) - \hat{v}(g)) \left(\frac{\#g!\,([n(n-1)/2)] - \#g - 1)!}{[n(n-1)/2]!} \right) \right] \tag{8}$$

where $\#g$ denotes the number of links in g.

Because $Y_i^{LBFN}(g,v)$ is the allocation of value to a given player i, it is obvious that the sum of all allocation is equal to the value function.

$$\sum_i Y_i^{LBFN}(g,v) = v(g) \tag{9}$$

As in the definition of the Shapley Value for conventional cooperative games, the LBFN allocation measures the contribution of links to the overall value of the network by calculating the value accrued from adding each link, and then averaging over all permutations in which the network may be formed. The difference between the LBFN allocation rule and the Myerson Value is that the Myerson Value assigns value to players rather than links, and that the LBFN allocation rule depends only on the monotonic cover of the value function, implying that the allocation is “being decided upon when the network is formed or can still be changed: at a time where there is still some flexibility in the network” (Jackson 2005).

Next, the Relative Bargaining Power of players is defined. 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

$$RBP_i^{LBFN}(g, v) = \frac{Y_i^{LBFN}(g, v)}{v(g)} \quad (10)$$

The Relative Bargaining Power of each player is represented as a percentage of the value of the entire network, and therefore the sum of the Relative Bargaining Powers of all players adds up to 1. This representation assists in understanding the relative shift in power that may arise from a change in the pipeline network.

5 Historical Background of the Case: From “Domestic” to “Transboundary” to “Dispute”

As of November 2012, Russia is the world’s largest exporter of natural gas, exporting to dozens of nations in the Eurasian continent through an extensive network of natural gas pipelines. And due to the complexity of this network and the geopolitical and geostrategic nature of natural gas as explained in this thesis, the trade of Russian natural gas has repeatedly been a source of tension and conflict, as most clearly embodied in the gas conflicts with Ukraine and Belarus.

The question of whether Russia is to blame or the transit countries are to blame is largely subjective, where some may side with Russia and claim that Ukraine and Belarus have used their strategic position as vital transit players to bargain with Russia and try to evade the rising prices of natural gas, while others may blame Russia for attempting to strengthen their position over these countries, in disguise as a diplomatic dispute over natural gas prices, to exert pressure, manipulate their leadership and infringe upon domestic affairs.

Both of these perspectives may be partially correct, but it is incorrect to assume that any of these players had wished for the current pipeline network structure or the resulting geopolitical power game. The underlying reason for the entangled geopolitical tension among these nations is the fact that the pipelines that pass through Ukraine, Belarus, Kazakhstan, Turkmenistan or any other former Soviet countries had been intended to be “domestic” pipelines. The arterial pipelines connected the gas fields directly to the German border, from where an extensive network of free-market, non-strategic pipelines existed. It was the dissolution of the Soviet Union and the resulting independence of countries such as Ukraine, Belarus and Central Asian nations that caused the arterial pipelines to become “transboundary” and thus highly geopolitical.

This is precisely the reason why this classic case of natural gas geopolitics was chosen for the analysis. From a network perspective, the Soviet Union Era was characterized by a very simple network that connects one node (the Soviet Union) directly to another node (the free trade economies of Western Europe), but with the collapse of the Soviet Union, 15 new nodes (the newly independent former Soviet nations) came into existence and the network’s complexity multiplied almost overnight. This sudden change in network structure was a nightmare for Russia, but from the academic perspective, the decades that followed the collapse of the Soviet Union are a rare specimen of countries heavily reliant on natural gas trade, exporters and importers alike, suddenly being confronted by a power game over the world’s most fragmented transboundary pipeline network. Therefore, although no other case of natural gas geopolitics may follow in the exact footsteps of this classical case, the implications are abundant and there is much for other countries or regions involved in natural gas trade to learn.

In this chapter, three historical phases that led to this classical case are highlighted and explained in depth. The first aspect is the history of natural gas use and pipeline formation in Russia, which as abovementioned, began as a simple domestic pipeline. The second aspect is the collapse of the Soviet Union which transformed the pipeline network into a fragmented, geopolitically sensitive network involving over a dozen stakeholders. The third and final aspect is the strategic tensions and so-called "gas disputes" that occurred after the collapse of the Soviet Union.

5.1 Phase 1: Formation of the Soviet Gas Network

The first recorded use of natural gas in Russia (or the Russian Empire) was 1819, but natural gas was still a mere 2 percent of Soviet primary energy consumption in 1953 (Victor et al 2006). It was not until 1956 that natural gas appeared in the Soviet economic planning, at which time it was still produced from smaller, dispersed fields to the west of the Ural Mountains, and sent to the industrial demand centers in present-day Ukraine, as shown in Figure 9.

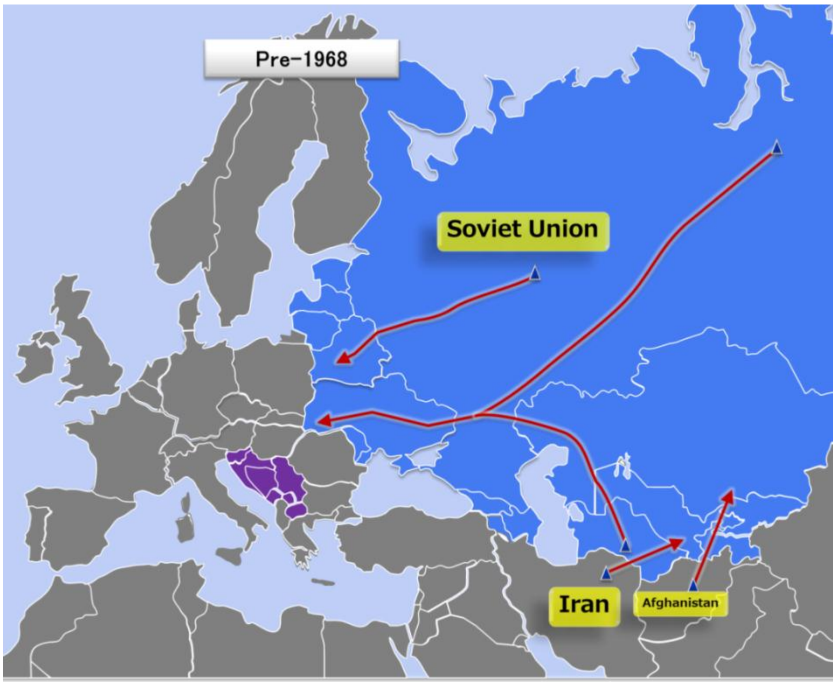


Figure 9 Natural Gas Pipelines, Pre-1968

(Figure drawn by author based on Victor et al 2006)

The first truly "transboundary" arterial pipeline was constructed in 1968, and named "Brotherhood" (Figure 10), and linked the Shebelinka gas fields close to Kiev, to Czechoslovakia, and later extended to Austria and Poland. In 1970, these were the only three countries in the world that imported natural gas from the Soviet Union, a sum of only 3.4 billion cubic meters (Shiobara 2007).

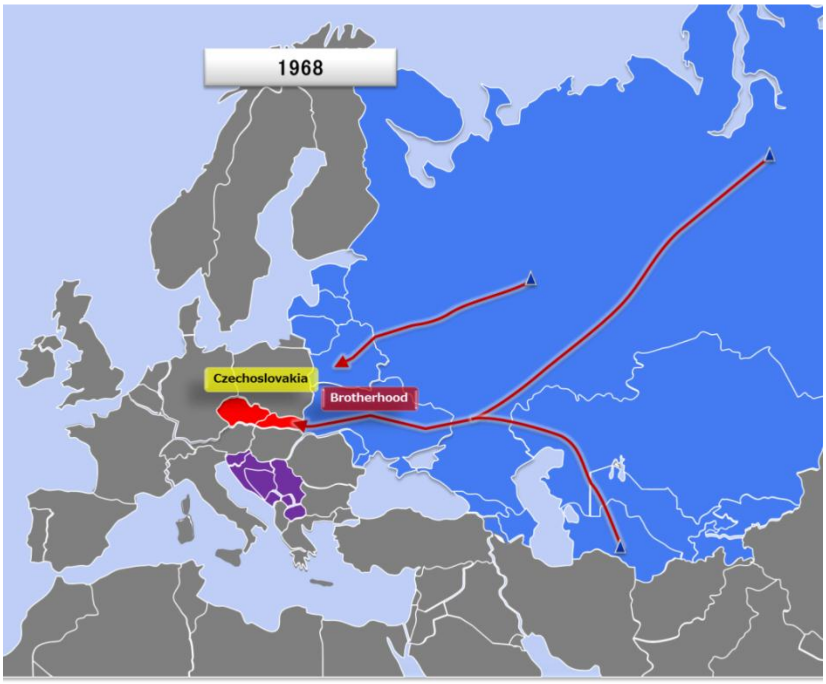


Figure 10 Natural Gas Pipelines and New Importers (1968)

(Figure drawn by author based on Victor et al 2006)

Natural gas gained importance after the oil shock of 1973. With oil prices skyrocketing and the security of supplies becoming increasingly under question, the opportunity for the Soviet Union to expand exports to the Western nations grew. The Western nations also shared a common goal to try to engage the Soviet Union into commercial exchange, and a transboundary infrastructure (as shown in Figure 11 and Figure 12 below) that would lead to a continuous and mutually beneficial trading relation between the two economic blocs was a way of easing tension between the conflicting spheres of the Cold War. The pipeline network reached its full capacity in 1991, and by this time the Soviet Union was exporting a sum of 63 billion cubic meters of natural gas to nations including Germany, Italy, France, Austria, Turkey, Yugoslavia, Finland and Switzerland. The participation of these countries in natural gas trade with the Soviet Union are illustrated in Figures 11 to 14 below (Victor et al 2006).

Figure 11 Natural Gas Pipelines and New Importers (1973)

(Figure drawn by author based on Victor et al 2006)

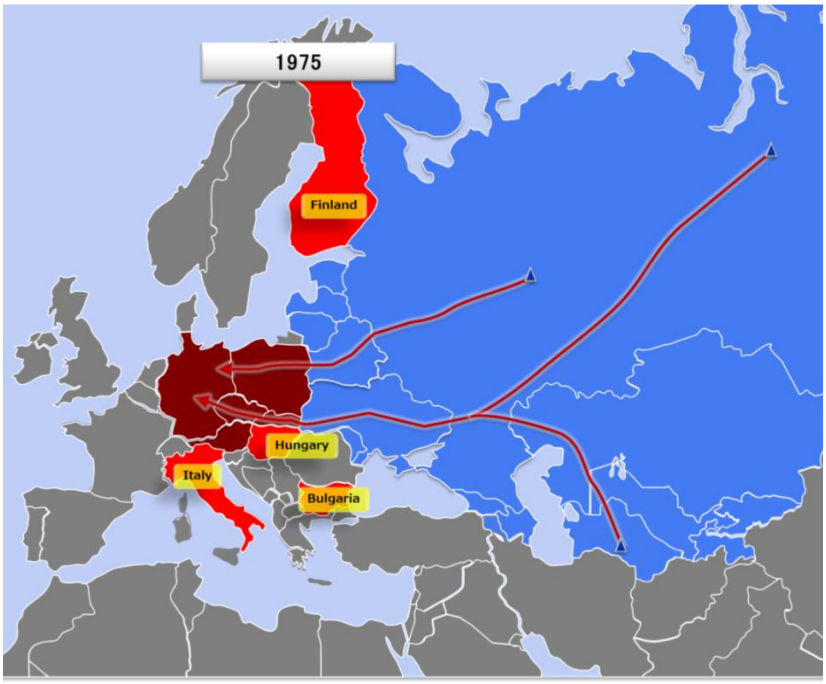


Figure 12 Natural Gas Pipelines and New Importers (1975)

(Figure drawn by author based on Victor et al 2006)

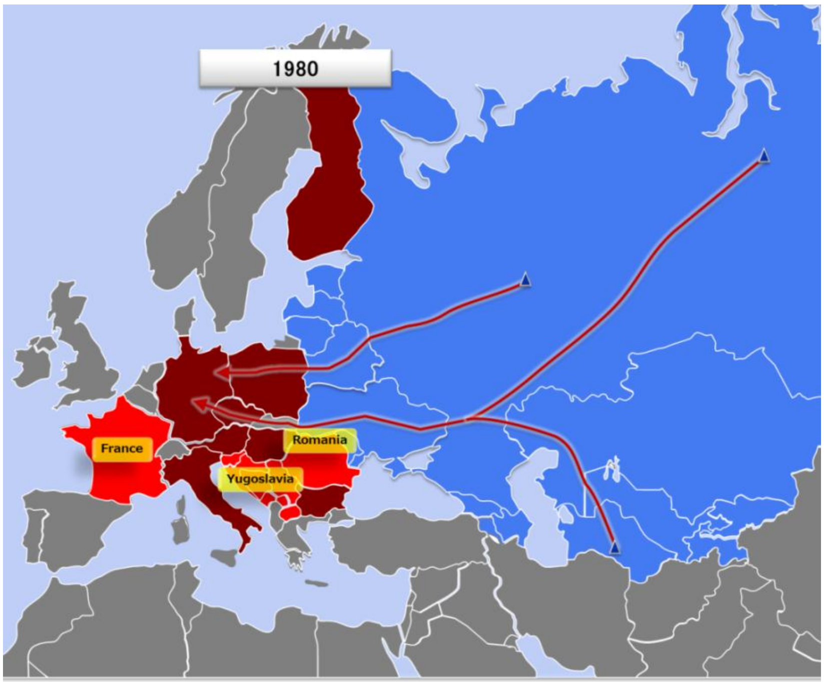


Figure 13 Natural Gas Pipelines and New Importers (1980)

(Figure drawn by author based on Victor et al 2006)

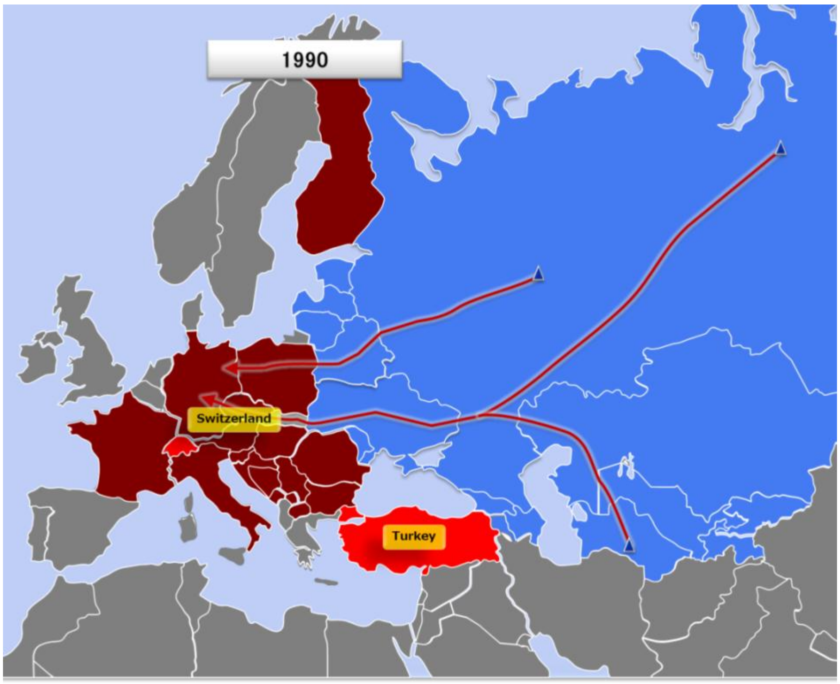


Figure 14 Natural Gas Pipelines and New Importers (1991)

(Figure drawn by author based on Victor et al 2006)

As Figure 14 shows, all of the countries importing natural gas from the Soviet Union were either directly connected to the Soviet Union (e.g. Turkey, Norway, Eastern European nations), or connected through a transit country that operates under the philosophy of free trade (e.g. Western European nations). Thus, the only geopolitical and geostrategic concern for importers was the direct relationship with the Soviet Union, in which natural gas trade was, as abovementioned, largely seen by both the Western world and the Soviet Union as a stabilizing factor rather than a source of tension and conflict.

5.2 Phase 2: Collapse of the Soviet Union and the Emergence of Transit Nations

The August 1991 coup is considered to be one of the most decisive moments that triggered the collapse of the Soviet Union. Initially “designed to halt the weakening of the centralized USSR”, the event “ironically hastened the Union's dissolution” (Soviethistory.org). Below in Figure 15 is a list of newly independent former Soviet Republics and their independence dates (either de Jure or de Facto).

Lithuania – March 11, 1990
Latvia – May 4, 1990
Georgia – April 9, 1991
Estonia – August 20, 1991
Latvia – August 21, 1991
Ukraine – August 24, 1991
Belarus – August 25, 1991
Moldova – August 27, 1991
Azerbaijan – August 30, 1991
Kyrgyzstan – August 31, 1991
Uzbekistan – September 1, 1991
Tajikistan – September 9, 1991
Armenia – September 21, 1991
Turkmenistan – October 16, 1991
Kazakhstan – December 16, 1991

Figure 15 Former Soviet Nations and their Independence Days

(Created by author based on data from CIA World Factbook)

The collapse of the Soviet Union is well recognized as one of the most important events in the past few decades of history, and has often been discussed extensively in the context of geopolitics. And as mentioned earlier in this chapter, in the realm of natural gas geopolitics, this event is the most crucial event leading to the decades of strategic tension among the countries involved in the trade of natural gas.

As mentioned in the introduction of this chapter, the natural gas pipelines were intended to be between one sovereign producing/exporting player (*i.e.* the Soviet Union) and many importing players (*i.e.* the Western and Northern European nations) that either were directly connected to the Soviet Union, or essentially acted in concert based on free trade (e.g. it was and still is unimaginable that Germany would act strategically to strengthen its grip on natural gas exported through its territory to Italy). Unilateral strategic moves were legally prohibited as well as politically and economically deterred. But the post-1991 landscape was vastly different, as apparent in Figure 16 below.

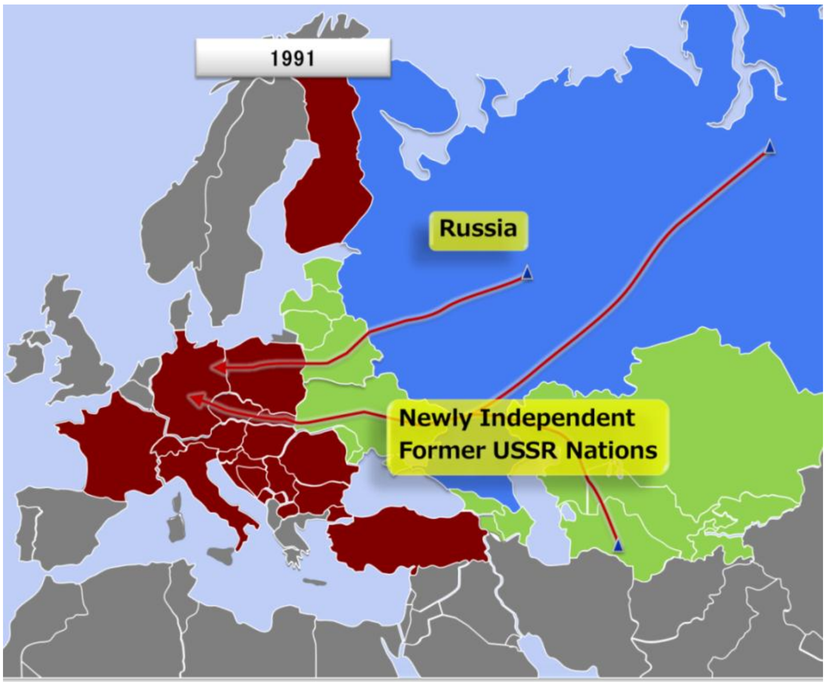


Figure 16 Natural Gas Pipelines and New Importers (1991)

(Figure drawn by author based on Victor et al 2006)

The Russian Federation, which is the successor of the Soviet Union, has lost all of its direct pipeline routes to the free-trading European nations with the exception of Finland. The two arterial pipelines that delivered all of the natural gas from the Urengoy Gas Fields came to pass through the two newly independent nations of Ukraine and Belarus, now key transit players that held control over the sections of the arterial pipelines that cross through their sovereign territory.

The collapse of the Soviet Union also brought about serious economic damage to the newly independent states, and Russia was not an exception. The Soviet economy "shrank by about 40 percent and total energy consumption declined by about one-third" (Victor et al 2006). As a result, Russia and the former Soviet nations' consumption of natural gas fell, and the production and transportation capacities were in excess. The resulting strategy was, naturally, to export the gas to the economically stronger Western importers in order to make full use of these capacities.

5.3 Phase 3: Gazprom's Plight and the Gas Disputes of the 1990s

As is well known, the Russian natural gas utility Gazprom is still essentially a state-owned enterprise, as with other resource entities in the Russian Federation (Gazprom 2009). Additionally, Gazprom's Soviet Gas Ministry-origin effectively obliged the entity to suppress domestic gas prices to low levels as was done in the Soviet Era. Although an important goal for Gazprom as a newly quasi-private entity was to boost profits, the strong domestic political challenges, that it would face in an attempt to raise domestic prices robbed Gazprom of this straightforward option, and gas prices rose only incrementally throughout the 1990s (Henderson 2011).

Therefore, naturally, Gazprom's strategy focused on two alternative strategies: increasing exports and raising prices for the exported natural gas. As mentioned in Chapter 1, natural gas's characteristic as a resource that is distributed unevenly and difficult to store have made the development of a global spot gas market very difficult, and a unified gas market has yet to exist. Gas prices are either determined at the three main regional gas markets or under bilateral price negotiations.

Therefore, while gas export prices to Western European nations have been designed to follow an oil price formula, export prices to former Soviet nations have been decided arbitrarily through bilateral negotiations. Until around 2003, countries that were still loosely under Russian political influence (e.g. Ukraine and Belarus) enjoyed natural gas prices that resembled Russian domestic gas prices, at approximately one-fifth that of Western European exports (Figure 17).

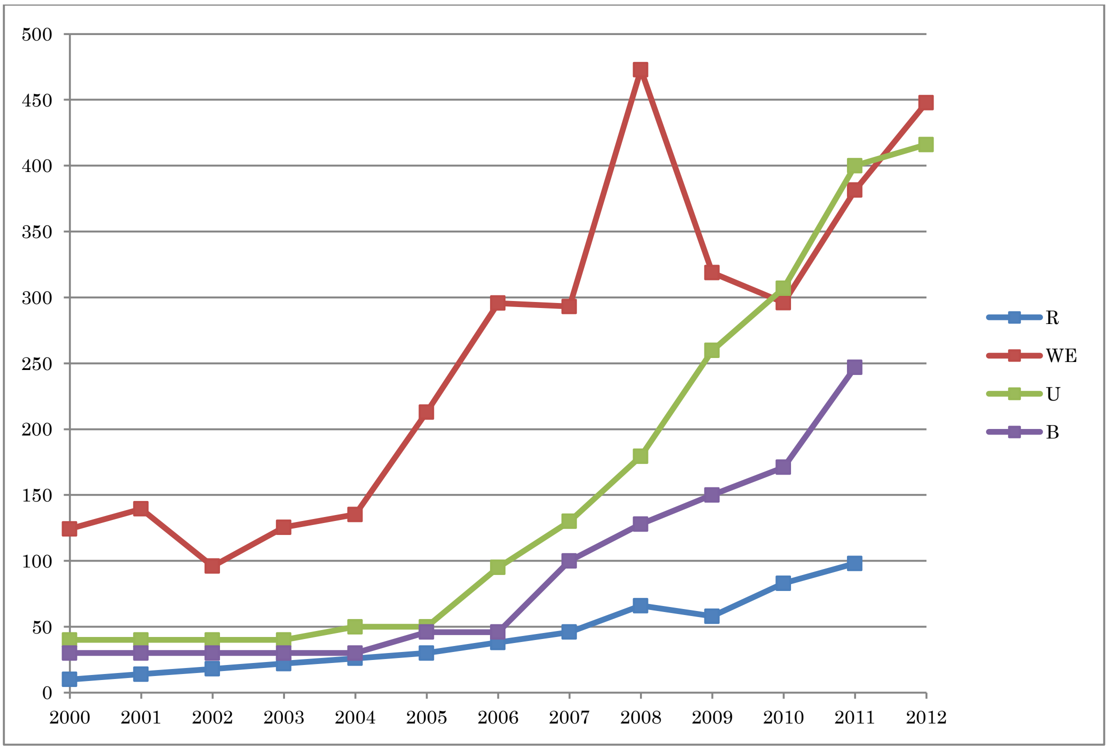


Figure 17 Gas Prices in Russia, Ukraine, Belarus and Western Europe (2000-2012)

(Graph Created by author based on IMF Commodity Prices and Articles on Gas Prices)

With domestic price increases deterred, Russia apparently decided to take a twofold strategy to increase exports to the high-priced importers (e.g. Western Europe), and to raise prices for the discounted former Soviet importers (e.g. Ukraine, Belarus). The former was not as easy as had been in the Soviet Era because, as mentioned in the previous section, almost all of Russia's export pipelines involved independent transit countries. The latter was difficult because some of these former Soviet importers, especially Ukraine, not only resisted price raises but even failed to make gas payments as scheduled.

Throughout the 1990s, Gazprom and Ukraine were in constant conflict over Ukraine's unwillingness to pay for the accumulated debts that were the result of natural gas imports (Victor et al 2006). While other newly independent nations such as the Baltic countries or countries that were semi-independent during the Soviet era but belonged to the Soviet bloc (e.g. Czech Republic, Slovakia) raced to join the Western countries (as seen in their strong lobbying to join the European Union) and were consequently required to pay Western European prices, countries like Ukraine and Belarus remained, perhaps without a choice, in the Russian sphere of influence. It may be speculated that Ukraine's unwillingness to immediately clear the gas debt was the result of this semi-consanguine relationship, where Ukraine hoped that Russia would take a lenient posture. Yet, these relations quickly soured and Gazprom/Russia and Ukraine entered an era of constant negotiation and bargaining over gas prices, transit fees and debt repayment, consummating into what is known as the Russo-Ukrainian Gas Conflicts, the first of which took place as early as October 1992.

The well-known and well-remembered Russian-Ukrainian gas disputes were those that took place in more recent years (2005 and onwards), but in fact, the two countries had been in constant dispute since immediately after the fall of the Soviet Union. "In 1992, 1993 and 1994, during disputes about debts and non-payment, Russia suspended supplies. This led to illicit diversions of gas from transit pipelines by Ukrainian companies and institutions in September 1993 and November 1994" (Pirani 2009).

Therefore, naturally, Russia attempted to find alternate routes to export natural gas to the demand centers in Western Europe. Western European countries, from whose perspective the issue was a compounded risk of having Ukraine as a transit country and

Russia as the importer, attempted to find alternate sources of natural gas, or alternate sources of energy in order to decrease its dependence on Russian natural gas.

In summary, the years following the dissolution of the Soviet Union are characterized by all stakeholders of natural gas trade scurrying to cope with the drastically altered natural gas pipeline network. The once-domestically Soviet network of natural gas pipelines was transformed into a fragmented transboundary network of over a dozen nodes with the newly independent but economically fragile Ukraine as a vital player involved in the transportation of over 90% of gas exports. Russia struggled to maintain control of and revenue from natural gas trade, newly independent states struggled to sustain discounted gas prices, and the Western importers struggled to attain energy security in face of an increasingly disputing set of exporting and transiting nodes. And thus, a wide variety of additional or alternative pipeline plans were devised, one of which is the main case of this thesis, the Nord Stream pipeline

6 The Case: Nord Stream Pipeline

6.1 Underwater Pipelines

In the last years of the 20th century, Russia was ambitiously exploring the possibility of building new transboundary pipelines in order to diversify its natural gas exports while bypassing the troublesome transit countries, especially Ukraine. One such example was the "Blue Stream" Pipeline, Gazprom's first plan for a deep-water gas pipeline. The Blue Stream Pipeline was "designed to sell natural gas that is said to be produced from Russia's Izonobilye Area to Turkey of 16 billion cubic meters (bcm) per year with a 1,289 km pipeline covering 396 km in the Russian Federation, 392 km under the Black Sea and 501 km between Samsun and Ankara after reaching Turkey's Samsun coast (Ozdemir 2007).

In February 2003 the first gas was transported through the Blue Stream Pipelines to Turkey. The Blue Stream Pipeline cost approximately $3.2 billion until operation, and some argue that "though the project qualified as an engineering triumph, it seems far less likely to be a commercial success" (Victor, et al. 2006). Although the commercial viability of Blue Stream is still under question, it opened way for a new class of natural gas pipelines: deep sea submarine pipelines that connect Russian sources directly to the importing nations.

The case dealt with in this thesis, the Nord Stream (Figure 18), is the most representative example of such deep sea pipelines. Of the numerous pipeline plans that have been announced in the two decades since the collapse of the Soviet Union, Nord Stream was one of the only plans that fructified into an operating pipeline.

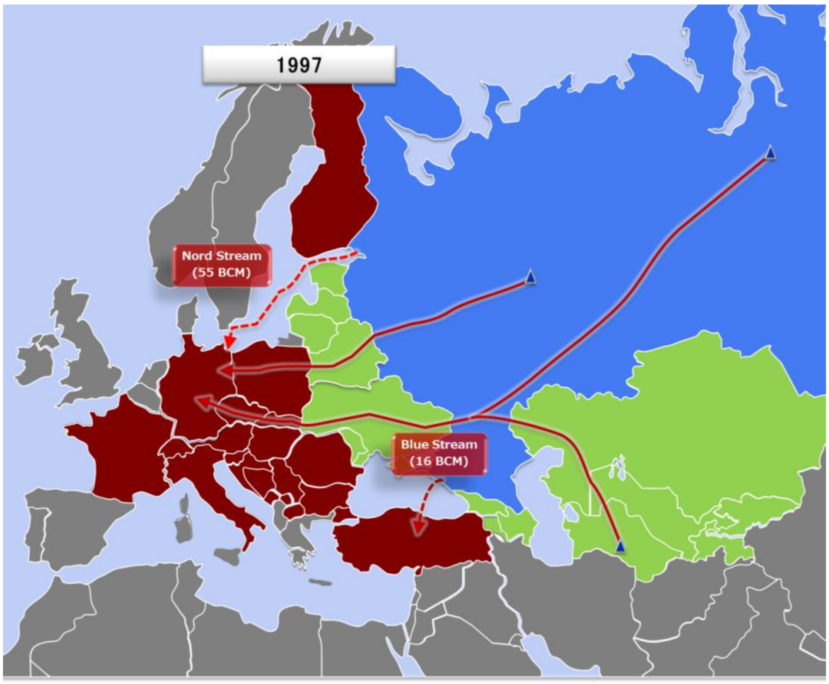


Figure 18 Proposed Pipelines (1997)

6.2 Nord Stream and the role of Maritime Transit Countries

The Nord Stream Pipeline is composed of two 1,224 kilometer offshore, deep-water pipelines that run through the Baltic Sea from Portovaya Bay near the Russian city of Vyborg to the German city of Germany's Baltic coast at Synergipark Lubmin in Greifswalder Bodden. It is "the most direct connection between the vast gas reserves in Russia and energy markets in the European Union. When fully operational in the last quarter of 2012, the twin pipelines will have the capacity to transport a combined total of 55 billion cubic meters of gas per year for at least 50 years" (Nord Stream AG 2006).

The pipeline project began with the formation of a joint company between Gazprom and the Finnish company Neste in 1997, but it was not until 2005 that an agreement was finally reached between JSC Gazprom, BASF AG and E.ON AG to form Nord Stream AG and begin construction (Nord Stream AG 2006). One of the significant causes of this delay was the existence of "maritime transit players" that held decisive power in the planning and construction phases of the project.

Although the Nord Stream Pipeline is a direct connection between Russia and Germany, it crosses the Exclusive Economic Zones of Russia, Finland, Sweden, Denmark and Germany, as well as the territorial waters of Russia and Germany. Therefore, in the planning and construction phases, the consent of these countries was crucial. But, these countries would not be considered "transit countries" once the pipelines are laid, because the moment they sign the contract that allows for the pipelines to pass through their Exclusive Economic Zones, these countries forfeit most of their decision-making power over the pipeline.

In other words, while a traditional transit player like Ukraine has an option to prevent the construction of a pipeline within its territory as well as an option after the construction to retain its rights for control over the section of the pipeline that passes through its own land, the power of "maritime transit countries" is limited to the planning and initial construction phases. Yet, this does not mean that these countries' influence was trivial in the Nord Stream Pipeline Plan, for the "credibility" of Gazprom's plan announcement relied heavily on the consent of these nations for the construction of this potentially environment-unfriendly underwater pipeline.

And finally on November 2011, after a decade from inception, the Nord Stream Pipeline was formally opened and natural gas began to flow. The attendance of the two heads of state German chancellor Angela Merkel and the Russian president Dmitry Medvedev at the initial opening ceremony signifies the politicized nature of this project. As the "first Russian gas reached the German mainland at the north-eastern town of

Lubmin, Ms. Merkel said the 7.4 billion Euro project was a sign that Germany was 'expecting a safe and resilient partnership with Russia'" (Financial Times, November 8th, 2011).

Mr. Medvedev in turn commented that the dual pipes, the second of which will be finished next year, marked a 'new page' in relations" (Financial Times, November 8th, 2011). These official comments portray a constructive and forward-looking aspect of the pipeline, but the same article mentions an important comment made by the current (as of November 2012) President Putin warning "Ukraine in particular that 'the temptation to benefit' from its 'exclusive position' would now end" (Financial Times, November 8th, 2011). This comment very clearly summarizes Russia's political intention with regard to this pipeline plan.

The following chapter explains in detail how the games are set up in this thesis.

7 Two Game Setups: “HI-Style LBFN” and “NH-style LBFN”

As mentioned in Chapter 2, one of the main purposes of this thesis is to apply the link-based flexible allocation rule to the case of natural gas trade between Russia and Europe, with a special emphasis on the Nord Stream Pipeline, in order to gain insight into the causes of the geopolitical tension among the nations involved. Another important purpose of this thesis is to gain insight into the explanatory power of the model in comparison to models used in the existing literature.

Therefore, it is of importance to first model a game that closely resembles the previous literature, namely Hubert and Ikonnikova (2011). Then, in order to utilize the advantages of the Network Game and Link-based Flexible Network Allocation, this thesis models the same cases in a different setup. The former will be referred to as HI-Style LBFN and the latter as NH-style LBFN.

7.1 HI-Style LBFN

In Hubert and Ikonnikova (2011), the three strategic players were *Russia*, *Ukraine* and *Belarus*. Therefore, the set of players is defined as $N = \{R, U, B\}$ using the capital initials of the countries *Russia, Ukraine and Belarus.*

Next, the status quo is defined. In the status quo, there exist pipelines between Russia and Ukraine as well as Russia and Belarus that have existed since the Soviet Union days. Using the names of pipelines from Hubert and Ikonnikova (2011), l_{RU} is referred to as *South*, and l_{RB} as *Yamal*. The *Nord Stream* pipeline is defined as a direct link l_{RWe} between Russia and Western Europe, where *We* indicates *Western Europe*, which is not a strategic player, but essentially the market to which all of these pipelines connect. The resulting network structure is shown in Figure 19, where each of the links $L = \{RU, RB, RWe\}$ allows for gas to be exported from Russia to the Western European market.

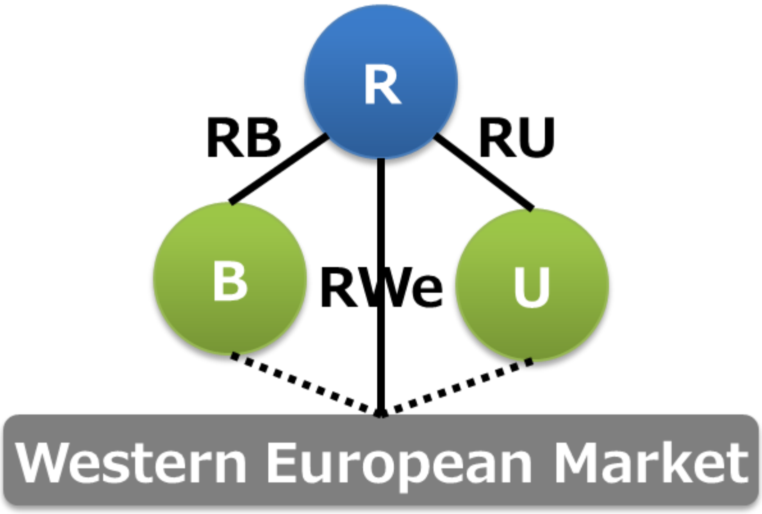


Figure 19 Proposed Pipelines (1997)

The existing links and the proposed link l_{RWe} are as shown above in Figure 19. As mentioned in Chapter 4, a value is assigned to each of these links, and the sum of the values becomes the value function of the graph. Given link ij, the value of the link is defined as

$$u_{ij}(\mathrm{g}) = (p - T_{ij})x_{ij} \tag{11}$$

Here, p (\$,United States Dollars) is the price of natural gas, T_{ij} (\$/thousand cubic meters) is the link-specific transportation cost per unit (tcm, thousand cubic meters) of gas, and x_{ij} (tcm) is the quantity of natural gas exported through link ij. Hubert and Ikonnikova (2011) used an inverse demand function for the price of Russian natural gas, but since natural gas prices are highly political and arbitrary, this thesis did not assume that the price of natural gas was determined according to the quantity traded in the pipeline network, but rather considered price negotiations to be affected by the Relative Bargaining Power calculated from the model.

In other words, rather than assigning a different gas price to each of the scenarios, a fixed gas price was assigned for all of the scenarios for the sake of calculating Relative Bargaining Power based on a common premise. Further, it is interpreted that some countries (e.g. Ukraine, Belarus) received price discounts as a result of their strong Relative Bargaining Power. The price p was set at a somewhat arbitrary price of $200, based on the average price traded in Europe around year 2002-2005 when the Nord Stream pipeline was in discussion. A sensitivity analysis was conducted in Chapter 8 to see that the estimation of this price p does not have a significant impact on the outcomes of the analysis.

The link-specific transportation cost per unit of gas T_{ij} is defined according to the calibration by Hubert and Ikonnikova (2011), but the capital cost was treated separately.

$$T_{ij}(\mathrm{g}) = \frac{(m_{ij} + \beta_{ij} \times MC_0)(e^{\beta_{ij} \times \mu_{ij}})}{\beta_{ij}} \tag{12}$$

Here, m_{ij}($/tcm/100km) is the management and maintenance cost, which is assumed to be proportional to the distance and quantity of natural gas transported. μ_{ij}(100km) is the length of the pipeline, β_{ij}(%/100km) is the amount of gas used to power compressor stations located along the pipeline, and MC_0 ($/tcm) is the marginal cost of production.

Hubert and Ikonnikova (2011) modeled a total of seven scenarios including the status quo. In this thesis, four of these scenarios (*Status Quo*, *South Upgrade*, *Yamal 2* and *Nord Stream) are modeled* for the purpose of comparison. The scenarios are shown in Figure 20 below.

The first scenario is the status quo in which the existing *South* pipeline that passes through Ukraine to Germany and the *Yamal* pipeline that passes through Belarus to Germany are the only two pipelines that exist. The allocation at the status quo is calculated by first assuming that all trade has stopped, and thus the value function is $v(\emptyset) = 0$. It is then assumed that the *South* and *Yamal* pipelines are in operation, and the value function is calculated when 70bcm is transported through *South*, and 28bcm through *Yamal*, as in Hubert and Ikonnikova (2011). The assumptions of the other scenarios are explained in Figure 20, and the specifications of scenarios are given in Table 2 below.

1. Status Quo

- The status quo in which the current *South* and *Yamal* pipelines exist.

***2. South* upgrade (Western Europe buys all)**

- Upgraded by 15 bcm/year, and Western Europe buys the entire amount through l_{RU}.

***3. Yamal* upgrade (Western Europe buys all)**

- Upgraded by 60 bcm/year, and Western Europe buys the entire amount through l_{RB}.

4. Nord Stream

- Between Greifswald, Germany and Vyborg, Russia. Maintenance costs higher due to the offshore nature. 72bcm/year.

Figure 20 The Scenarios in HI-Style LBFN

Table 2 Scenario Specification in HI-Style LBFN

Scenario	Links	Maintenance m_i [$/tcm/100km]	Compressor Gas β_{ij} [%/100km]	Length μ_{ij} [100km]	Quantity Traded x [bcm]	Difference With Status Quo [bcm]
Status Quo	RU	0.1	0.25	20	70	
	RB	0.1	0.25	16	28	
South Upgrade	RU	0.1	0.25	20	85	15
	RB	0.1	0.25	16	28	0
Yamal	RU	0.1	0.25	20	70	0
	RB	0.1	0.25	16	88	60
Nord Stream	RU	0.1	0.25	20	70	0
	RB	0.1	0.25	16	28	0
	Rwe	0.2	0.5	31	55	55

7.2 NH-Style LBFN

For NH-style LBFN, the set of players is defined as $N = \{R, U, B, We\}$, using the capital initials of the countries *Russia*, *Ukraine*, *Belarus* and *Western Europe*. *Western Europe* is mainly composed of *Germany* and *Italy*, which are by far the largest importers of Russian natural gas. Combining the two countries as one strategic player *Western Europe* can be justified because membership in the European Union forbids any strategic move within the European Union that may be a hindrance to free trade and the rule of law (e.g. *Germany* refusing a contracted transit of natural gas to *Italy*).

In the status quo, there exist pipelines between Russia and Ukraine as well as Russia and Belarus similarly to HI-style LBFN, but the major difference here is that the link from Russia to Ukraine and the link from Ukraine to Western Europe are treated as separate, independent links. The same applies for the link from Russia to Belarus and the link from Belarus to Western Europe. Hence, the natural gas pipeline network in the status quo is $L = \{RU, RB, UWe, BWe\}$. Therefore, if using the names of pipelines from Hubert and Ikonnikova (2011), $l_{RU} + l_{UWe}$ would be *South*, and $l_{RB} + l_{BWe}$ would be *Yamal*. The capability of this model to define pipelines strictly as a link between two countries allows for additional flexibility, and thus the *Nord Stream* pipeline can be defined as a direct link l_{RWe} between Russia and Western Europe.

NH-Style LBFN is able to treat Ukraine and Belarus not only as transit countries in the trade between Russia and the Western European market, but also as consumers of natural gas. Demand for natural gas in these countries for the years 2002, 2006 and 2010 are given in Table 3 below.

Table 3 Demand for Natural Gas in Ukraine and Belarus (bcm/yr)

	2002	2006	2010
Ukraine	85.2	99.7	102.8
Belarus	18.1	21.0	21.5
Western Europe	528.1	623.2	632.6

(Source: Jaffe and Hayes 2006)

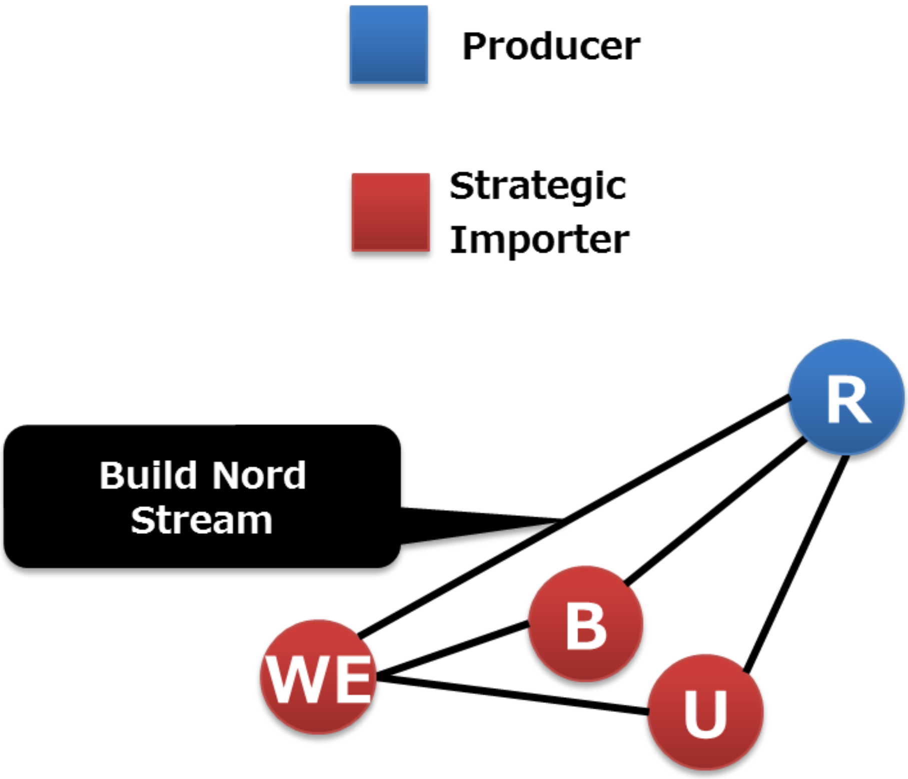


Figure 21 The Pipeline Network Structure in NH-style LBFN

The pipeline network scenarios treated in this thesis are as explained in Figure 22. The main difference with HI-style LBFN is that in the “upgrade” scenarios, the additional capacity can be used to supply any of the consumers located along the pipeline’s path. For example, if *South* is upgraded by 15 bcm/year, this additional amount can be exported entirely to Western Europe, entirely to Ukraine, or to both consumers in any proportion.

Here, because the purpose is to examine the maximum effect that these scenarios may have on the Relative Bargaining Power of the players, the focus will be on the two extreme cases. For Belarus, because domestic demand for natural gas was 21.5 bcm/year and this entire amount was already imported from Russia, there cannot be a scenario in which Belarus alone imports additional gas. Therefore, extra gas in *Yamal* upgrade is imported by Western Europe.

1. Status Quo
   - Status quo in which the current *South* and *Yamal* pipelines exist.
2. *South* upgrade (Western Europe buys all)
   - Upgraded by 15 bcm/year, and Western Europe buys the entire amount through $l_{RU} + l_{UWe}$.
3. *South* upgrade (Ukraine buys all)
   - The *South* pipeline is upgraded by 15 bcm/year, and Ukraine buys the entire amount through l_{RU}.
4. *Yamal* upgrade (Western Europe buys all)
   - Upgraded by 60 bcm/year, and Western Europe buys the entire amount through $l_{RB+}l_{BWe}$.
5. *Nord Stream*
   - Between Greifswald, Germany and Vyborg, Russia. Maintenance costs higher due to the offshore nature. 72bcm/year.

Figure 22 The Scenarios in NH-Style LBFN

The actual quantity of natural gas imported by Western Europe through Ukraine was as shown in Figure 23 below. The amount was approximately 115 bcm/year until 2009, after which it dropped to below 100 bcm/year. Therefore, 115 bcm/year can be understood as the amount that Western Europe was willing to import through Ukraine in the status quo.

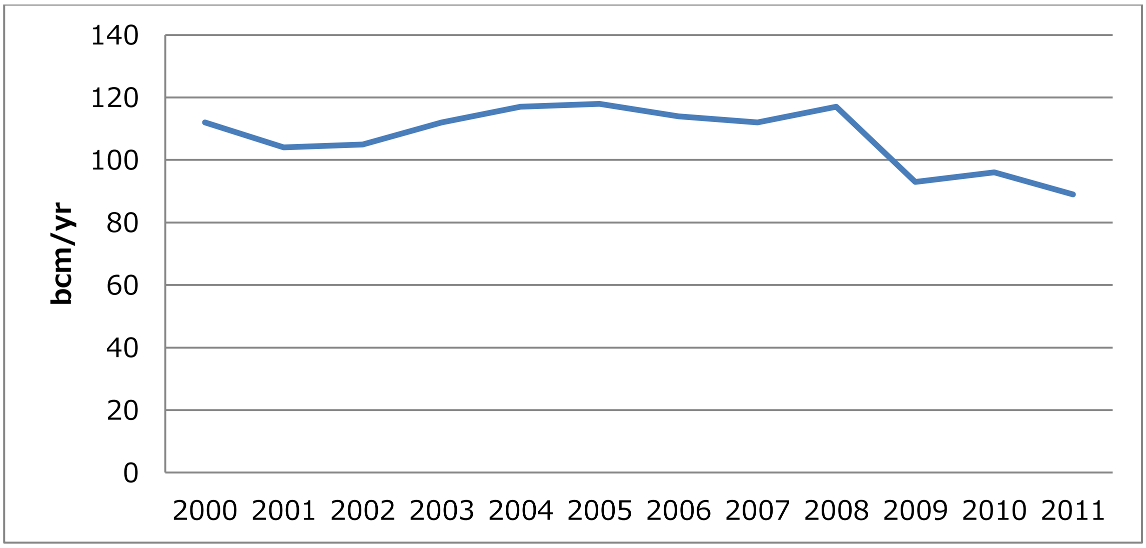


Figure 23 Russian Natural Gas Transported through Ukraine to Western Europe

It can be speculated that there exists some maximum rate of dependency that a country can permit for the import of a natural resource from a specific source, but such resource diversification strategies are never publicly announced. Therefore, it is very difficult to know how much energy a player like Western Europe is willing to import from a strategic exporter like Russia. It would be highly unlikely that Western Europe would be willing to import all of its natural gas solely from Russia.

Yet, given the fact that in this thesis, strategic player Western Europe is a group of over a dozen sovereign nations that together have a strong demand of over 500 bcm/year (Shiobara 2007), it can be expected that the relationship between Russia and each of these countries is diverse enough that some of these countries would be able to import the additional quantity of natural gas that would flow through the pipelines to Western Europe. For example, the *South Upgrade (Western Europe Buys All)* scenario is a mere 15 bcm/year increase for Western Europe, which can be assumed to be an amount that one of the countries in Western Europe would be more than willing to purchase. The *Yamal Upgrade (Western Europe Buys All)* scenario is a stronger upgrade plan in which an extra 60 bcm/year is available, but again, this is still an order of magnitude smaller than the aggregate demand in Western Europe, and is most likely absorbable. Finally, *Nord Stream* is a 72 bcm/year pipeline. To evaluate the maximum impact of this pipeline, it is assumed that Western Europe increases its import from Russia by the full 72 bcm/year. In other words, Western Europe imports both the 115 bcm/year that they had been importing through Ukraine and the additional 72 bcm/year through *Nord Stream*.

For each of the scenarios defined in Figure 22, specific pipeline specifications are defined as shown below in Table 4. The values for maintenance fees and the amount of gas used to power compressors are borrowed from the calibration by Hubert and Ikonnikova (2011), and thus are identical to HN-style LBFN. The length of pipelines is roughly estimated to be divided in half along the existing pipeline paths (e.g. The *South* pipeline is divided into a 1000km pipeline between Russia and Ukraine, and a 1000km pipeline between Ukraine and Western Europe). The length of the *Nord Stream* pipeline and the quantities of gas traded through each of the links are based on are mainly based on data published in Gazprom’s annual reports. The rightmost column shows the change in capacity in each of the links for each scenario.

Table 4 Specifications of Pipelines

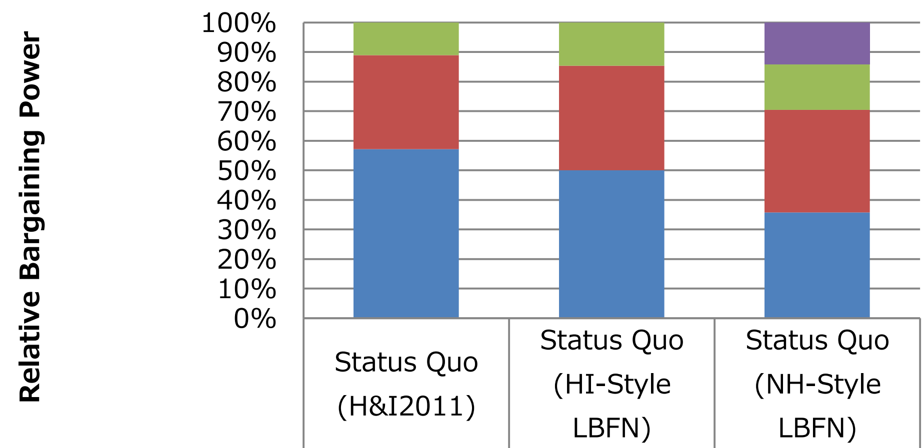
Scenario	Links Involved	Maintenance m_i [$/tcm/100km]	Compressor Gas β_{ij} [%/100km]	Length μ_{ij} [100km]	Quantity Traded x [bcm]	Difference from Status Quo
1: Status Quo	RU	0.1	0.25	10	56.2	
	RB	0.1	0.25	8	21.5	
	Uwe	0.1	0.25	10	115	
	Bwe	0.1	0.25	8	28	
2: South Upgrade (WE Buys All)	RU	0.1	0.25	10	56.2	0
	RB	0.1	0.25	8	21.5	0
	Uwe	0.1	0.25	10	155	15
	Bwe	0.1	0.25	8	28	0
3: South Upgrade (U Buys All)	RU	0.1	0.25	10	71.2	15
	RB	0.1	0.25	8	21.5	0
	Uwe	0.1	0.25	10	115	0
	Bwe	0.1	0.25	8	28	0
4: Yamal Upgrade (WE buys all)	RU	0.1	0.25	10	56.2	0
	RB	0.1	0.25	8	21.5	0
	Uwe	0.1	0.25	10	115	0
	Bwe	0.1	0.25	8	88	60
5: Nord Stream	RU	0.1	0.25	10	56.2	0
	RB	0.1	0.25	8	21.5	0
	Uwe	0.1	0.25	10	115	0
	Bwe	0.1	0.25	8	28	0
	Rwe	0.2	0.5	31	55	72

8 Results: Relative Bargaining Powers

The Relative Bargaining Powers yielded by each model, (i) HI-Style LBFN and (ii) NH-style LBFN, are compared to the results from Hubert & Ikonnikova (2011) in order to gain insight into the validity of the model applied in this thesis. Further, as mentioned in the previous chapter, there is a strong condition in which the price of natural gas p is arbitrarily fixed at \$200, and therefore a sensitivity analysis was conducted for prices from \$150 to \$450 in increments of \$50 to verify that a different price for natural gas would not generate results that are vastly different from what would be forecasted at the \$200 price.

8.1 Status Quo Scenario (Figure 24)

(i) HN-Style LBFN



	Status Quo (H&I2011)	Status Quo (HI-Style LBFN)	Status Quo (NH-Style LBFN)
WESTERN EUROPE	0.0%	0.0%	14.2%
BELARUS	11.10%	14.7%	15.4%
UKRAINE	31.80%	35.3%	34.6%
RUSSIA	57.10%	50.0%	35.8%

Figure 24 Relative Bargaining Power in Each Model at Status Quo

In the status quo scenario, the results from the HI-Style LBFN are similar to the results from Hubert and Ikonnikova (2011). This similarity was expected since the HI-style LBFN was set up precisely as an attempt to confirm that with similar calibration, the two models would yield similar results, and would thus be comparable. If the results that HI-Style LBFN yields for the other scenarios are similar to the results from Hubert and Ikonnikova (2011), it can then be concluded that the two models are indeed comparable.

The sensitivity analysis yields results that are consistent for all prices, as shown in Figure 25.

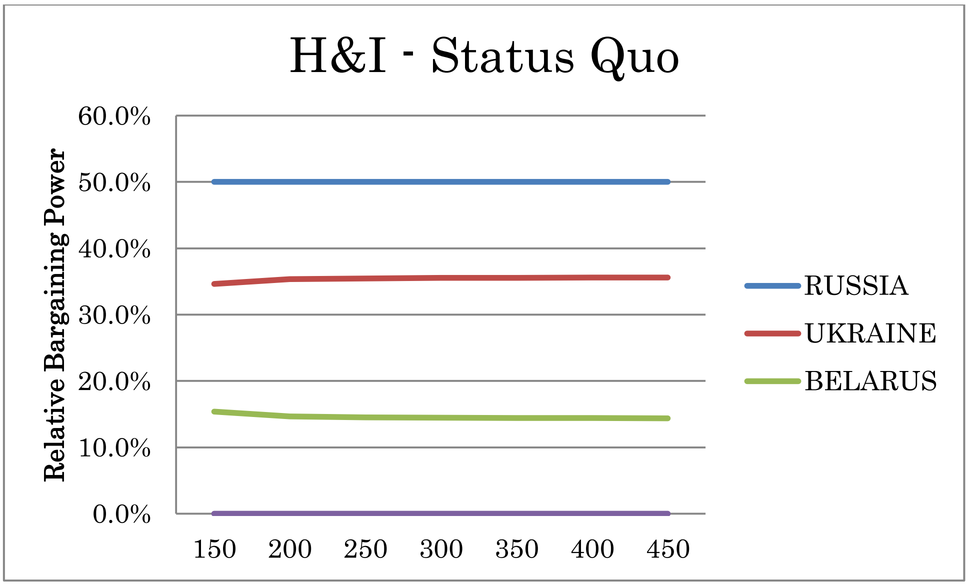


Figure 25 Sensitivity Analysis for H&I Status Quo

(ii) NH-Style LBFN

At a glance, the NH-Style LBFN yielded results that seem different from Hubert & Ikonnikova (2011), because Russia's Relative Bargaining Power is computed to be about 20% lower than the results from Hubert and Ikonnikova (2011). Yet, this difference is expected, given the fact that Hubert and Ikonnikova (2011) does not include Western Europe as a strategic player. In the context of natural gas geopolitics, Western European countries are clearly seen as a significant strategic player and the assumption by Hubert and Ikonnikova (2011) that Western Europe would passively accept any of the coalition structures given by Russia and the transit countries is ungrounded. For example, Nord Stream is a pipeline that is jointly owned and operated by Russia and Western European nations, and if Western Europe decided not to import any natural gas through Nord Stream, the pipeline would yield no value. Therefore, it is critical to include Western Europe as a strategic player in order to model these strategic relations.

In NH-style LBFN, the sum of the Relative Bargaining Powers of Russia and Western Europe resembles Russia's Relative Shapley Value in Hubert and Ikonnikova (2011) and HI-Style LBFN. Therefore, it can be interpreted that the 57.1% power that Russia boasts in Hubert and Ikonnikova (2011) and the 50% in HI-Style LBFN can be interpreted as the sum of the Relative Bargaining Powers of Russia and Western Europe, and that NH-Style LBFN has successfully isolated Western Europe's share of power from that of Russia.

The sensitivity analysis, as shown in Figure 26, predicts that Ukraine's Relative Bargaining Power would surpass that of Russia and Western Europe's Relative Bargaining Power would surpass that of Belarus at the price of $250/tcm. This can be understood intuitively because higher gas prices would make Russia more heavily dependent on the large importer (i.e. Western Europe) and main transit country (Ukraine).

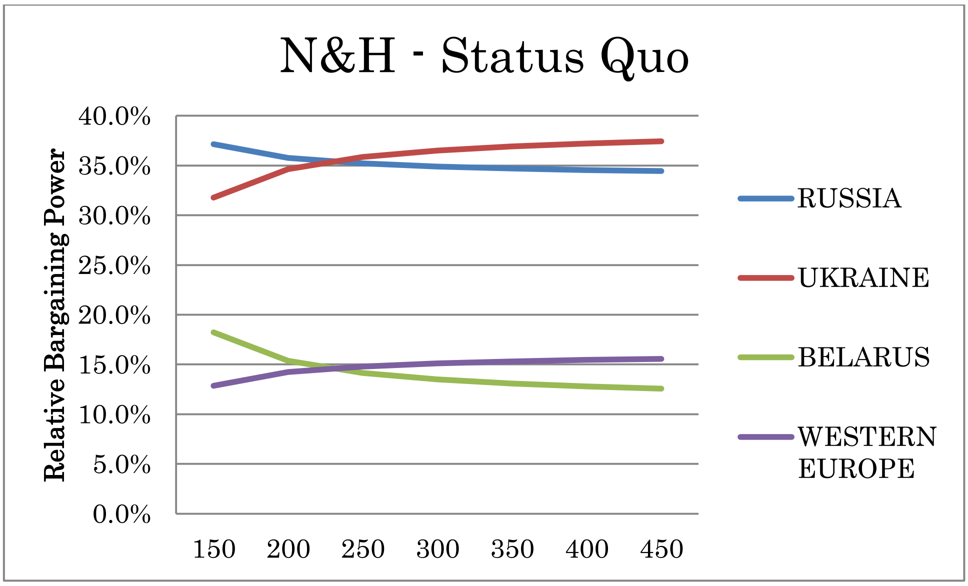
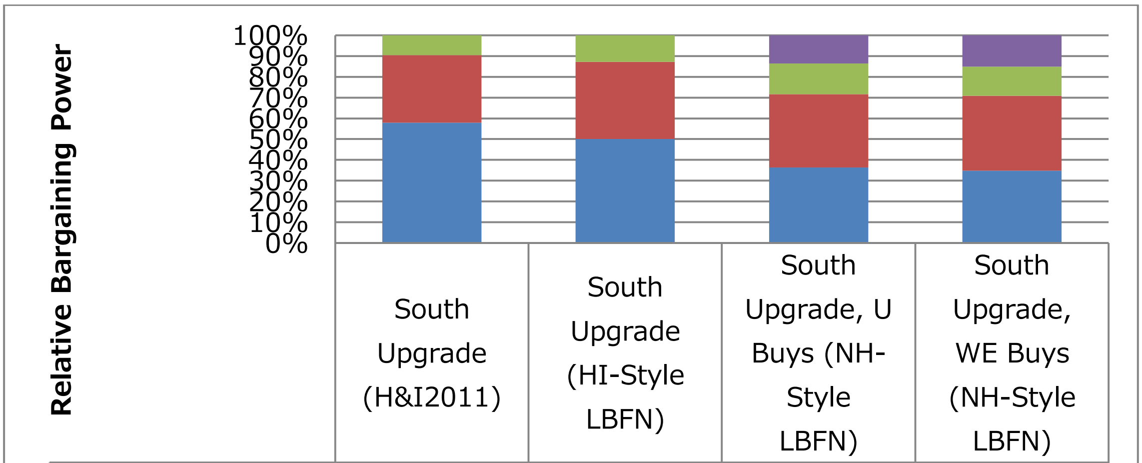


Figure 4 Sensitivity Analysis for N&H Status Quo

8.2 *South* Upgrade Scenario (Figure 27)



	South Upgrade (H&I2011)	South Upgrade (HI-Style LBFN)	South Upgrade, U Buys (NH-Style LBFN)	South Upgrade, WE Buys (NH-Style LBFN)
WESTERN EUROPE	0.0%	0.0%	13.6%	15.1%
BELARUS	9.60%	12.8%	14.7%	14.1%
UKRAINE	32.50%	37.2%	35.3%	35.9%
RUSSIA	57.80%	50.0%	36.4%	34.9%

Figure 5 Relative Bargaining Power in Each Model in South Upgrade Scenario

(i) HI-Style LBFN

In the *South* Upgrade scenario, HI-Style LBFN again yielded results similar to those of Hubert and Ikonnikova (2011). *South* upgrade increased Russia' bargaining power by 0.7% and Ukraine's Relative Bargaining Power by 0.7% in Hubert & Ikonnikova (2011), while Belarus's Relative Bargaining Power decreased by 1.5%. Although Russia's Relative Bargaining Power remains unchanged in HI-style LBFN, Ukraine's increase of and Belarus's decrease of 1.9% resembles Hubert and Ikonnikova (2011).

As shown in Figure 28 below, the sensitivity analysis yields results in which a change in prices does not bring about a significant change in Relative Bargaining Power.

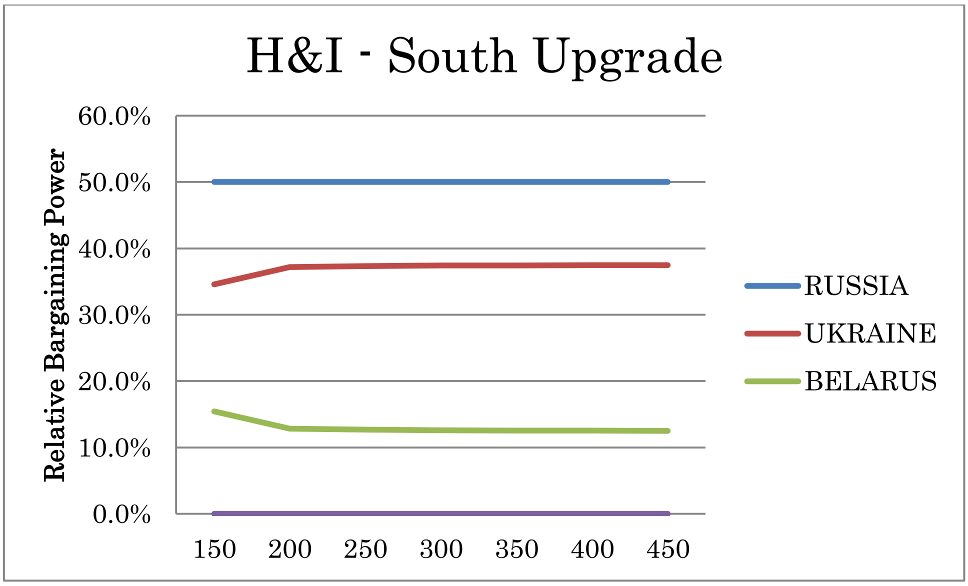


Figure 6 Sensitivity Analysis for H&I South Upgrade

(ii) NH-Style LBFN

With NH-style LBFN, the results of the analysis are quite different from Hubert and Ikonnikova (2011) or HI-style LBFN. The main difference is that two separate scenarios are analyzed for the *South* upgrade. In the first scenario, the 15 bcm/year additional capacity is imported solely by Ukraine, and in the other scenario, the same amount is imported solely by Western Europe.

In the former, Russia's Relative Bargaining Power increased by 0.8%, and Ukraine's Relative Bargaining Power increased by 1.0%, while Belarus's Relative Bargaining Power decreased by 1.0% and Western Europe's by 0.8%. This can be interpreted in several ways. Russia has a new outside option that allows it to sell 15 bcm/year to Ukraine rather than sell the same amount to Western Europe, or Russia is not economically sounder by an amount equal to the revenue generated from the 15 bcm/year sale. With either interpretation, Russia now has an outside option over Western Europe. Similarly, Ukraine theoretically gives Russia the freedom of bypassing Belarus by 15 bcm/year while sustaining the current economic conditions.

The sensitivity analysis shown in Figure 29 is similar to the status quo scenario, in that Ukraine and Western Europe surpass Russia and Belarus, respectively, at prices higher than $250. This can again be attributed to the importance of Western Europe as an importer and Ukraine as a transit country.

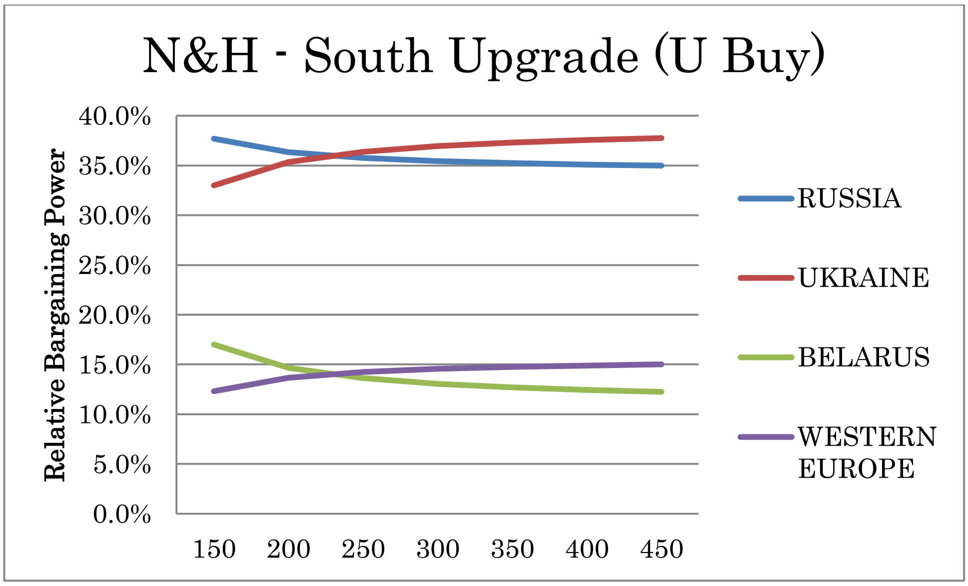


Figure 7 Sensitivity Analysis for N&H South Upgrade (U Buy)

In the scenario in which *South* is upgraded and Western Europe buys the entire amount, Russia loses bargaining power by 0.9%, Ukraine gains 1.2%, Belarus loses 1.2%, and Western Europe gains 0.9%. This can be interpreted as the opposite of the "Ukraine buys all" scenario. In either scenario, *South* upgrade is a scenario that benefits Ukraine, takes bargaining power away from Belarus, and benefits either Russia or Western Europe depending on the importer. From these results, it can be speculated that Russia would not upgrade *South* without a binding long-term contract that would assure that Ukraine would import a larger quantity of natural gas from Russia.

Figure 30 shows the sensitivity analysis for the scenario in which Western Europe buys the entire amount. The results are similar to the scenario in which Ukraine buys the entire amount except that Ukraine and Western Europe are even stronger than in the case where Ukraine buys the entire amount, and the power between Russia and Ukraine as well as Belarus and Western Europe are reversed at under $200/tcm.

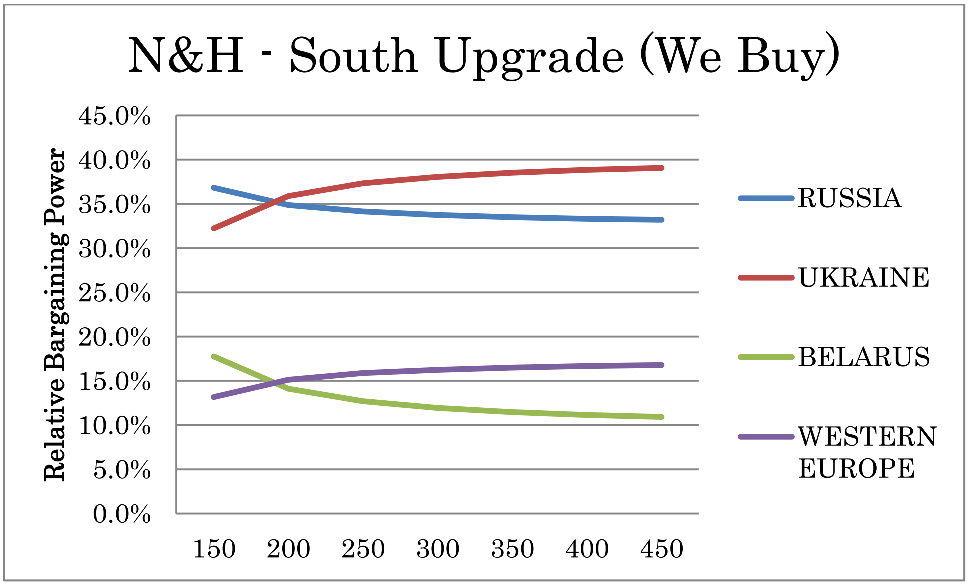
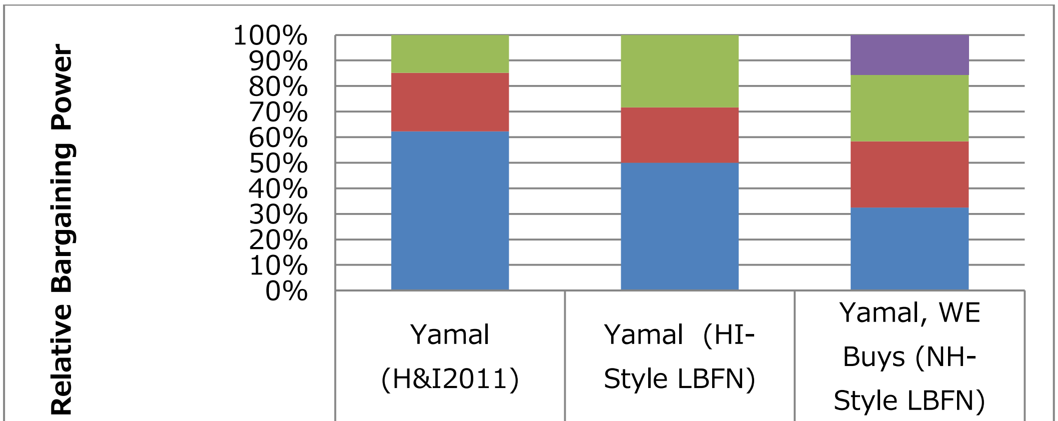


Figure 8 Sensitivity Analysis for N&H South Upgrade (We Buy)

8.3 Yamal Upgrade Scenario (Figure 31)



	Yamal (H&I2011)	Yamal (HI-Style LBFN)	Yamal, WE Buys (NH-Style LBFN)
WESTERN EUROPE	0.0%	0.0%	15.6%
BELARUS	14.30%	28.3%	26.0%
UKRAINE	22.20%	21.7%	26.0%
RUSSIA	60.30%	50.0%	32.5%

Figure 31 Relative Bargaining Power in Each Model in Yamal Scenario

(i) HI-Style LBFN

The *Yamal Upgrade Scenarios* yield results that are significantly different from Hubert and Ikonnikova (2011). In Hubert and Ikonnikova (2011), upgrading *Yamal* by 60 bcm/year gave Russia and Belarus each an additional 3.2% Relative Bargaining Power, and took 9.6% away from Ukraine. However, in HI-style LBFN, Russia's Relative Bargaining Power is unchanged, Ukraine's Relative Bargaining Power is decreased by a staggering 13.6%, and Belarus gains this entire amount. These results may be intuitive given that with this scenario, a total of 88 bcm/year passes through Belarus, while only 70 bcm/year passes through Ukraine.

The sensitivity analysis yielded results in which price differences does not have a significant effect on the Relative Bargaining Power, as shown in Figure 32.

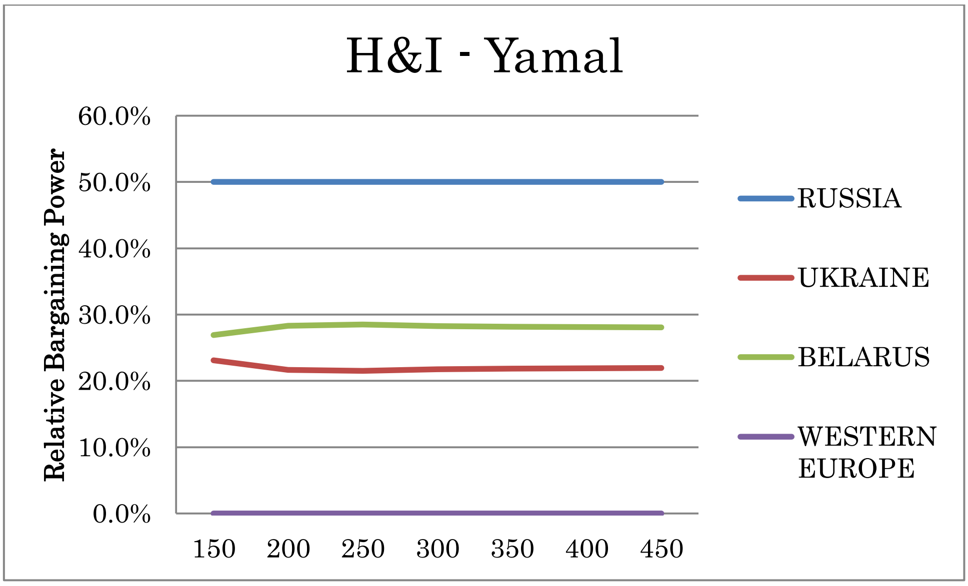


Figure 32 Sensitivity Analysis for H&I Yamal (B Buys)

(ii) NH-Style LBFN

NH-Style LBFN yields a more moderate effect. Russia loses 3.4%, Ukraine loses 8.9%, Belarus gains 10.3%, and Western Europe gains 2.0%. These results are interesting because Belarus's Relative Bargaining Power turns out to be identical to that of Ukraine, while the Relative Bargaining Power of Western Europe only slightly increases. At status quo, Belarus had little power due to its small domestic demand and the small capacity of the existing *Yamal* pipeline. The results of this *Yamal* upgrade scenario clearly show that Belarus has the potential to act as a bypass against Ukraine.

Yet, it is unlikely that Russia would risk losing its current Relative Bargaining Power in order to weaken Ukraine for two reasons. The first reason is the fact that Belarus is in a geopolitical position that is identical to that of Ukraine and that all of the tactics that Ukraine had resorted to in its disputes with Russia may also be used by Belarus. Therefore, in reality, Russia did not allow for increased gas transport through Belarus until Belarus consented to giving Russia a certain level of control over the Belarusian section of the *Yamal* pipeline. This deterred Belarus's option to unilaterally control gas trade through the *Yamal* pipeline (i.e. selling shares in the state-owned gas utility, Beltransgaz), and therefore the shift in Relative Bargaining Power predicted by this model has been mitigated by Russia.

The second reason is embodied in the sensitivity analysis, as shown in Figure 33 below, which provides another perspective in which increased prices would again reverse the Relative Bargaining Power between Ukraine and Belarus. Thus, even if Russia invests heavily on the Yamal bypass, market conditions may again put Ukraine in a position strong enough to bargain with Russia, and thus the plan did not suffice.

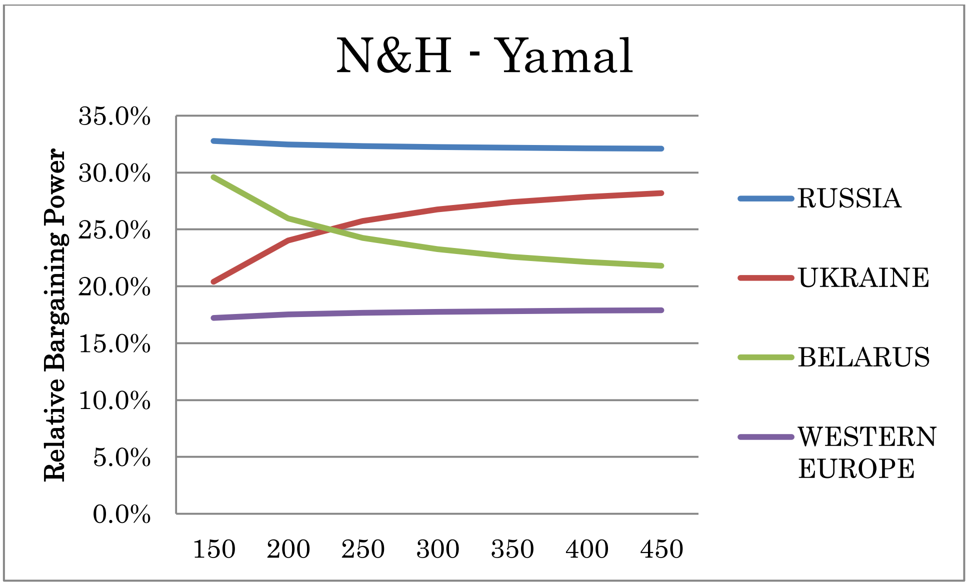
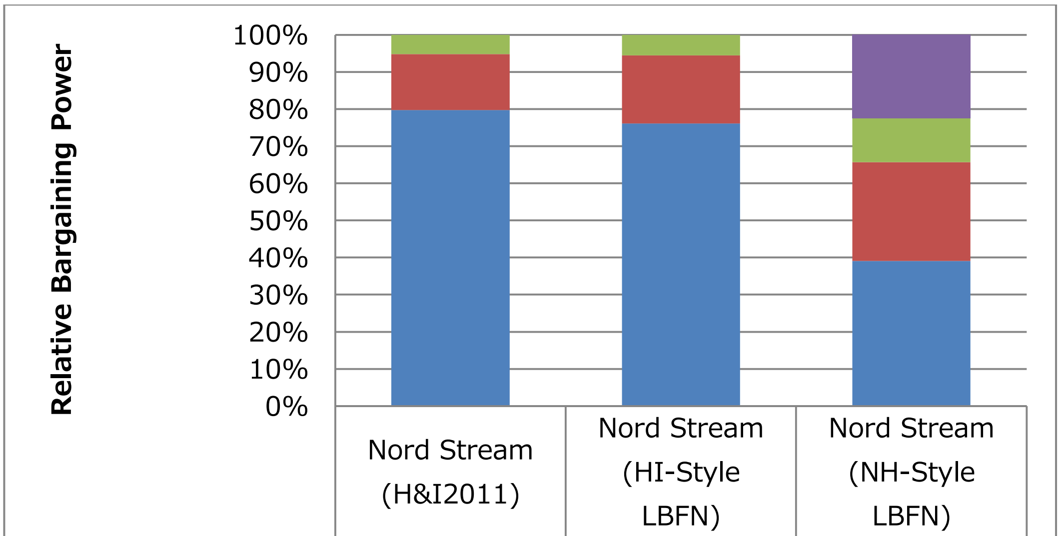


Figure 33 Sensitivity Analysis for N&H Yamal

8.4 *Nord Stream* Scenario (Figure 34)



	Nord Stream (H&I2011)	Nord Stream (HI-Style LBFN)	Nord Stream (NH-Style LBFN)
WESTERN EUROPE	0.0%	0.0%	22.5%
BELARUS	5.20%	5.6%	11.8%
UKRAINE	15.10%	18.3%	26.6%
RUSSIA	79.70%	76.1%	39.1%

Figure 34 Relative Bargaining Power in Each Model in Nord Stream Scenario

(i) HI-Style LBFN

The results of the HI-style LBFN *Nord Stream* scenario are similar to the results from Hubert and Ikonnikova (2011). In Hubert and Ikonnikova (2011), Russia's Relative Bargaining Power increased by 22.6%, Ukraine's decreased by 16.7%, and Belarus decreased by 5.9%. In HI-style LBFN, Russia's Relative Bargaining Power increased by 26.1%, Ukraine's decreased by 17.1% and Belarus by 9.1%. The resulting Relative Bargaining Power looks very similar, with the difference being only 3.6% for Russia, 3.2% for Ukraine, and 0.4% for Belarus.

The sensitivity analysis yielded surprisingly stable results, in which a change in prices resulted only in a change of Relative Bargaining Power of below 1%.

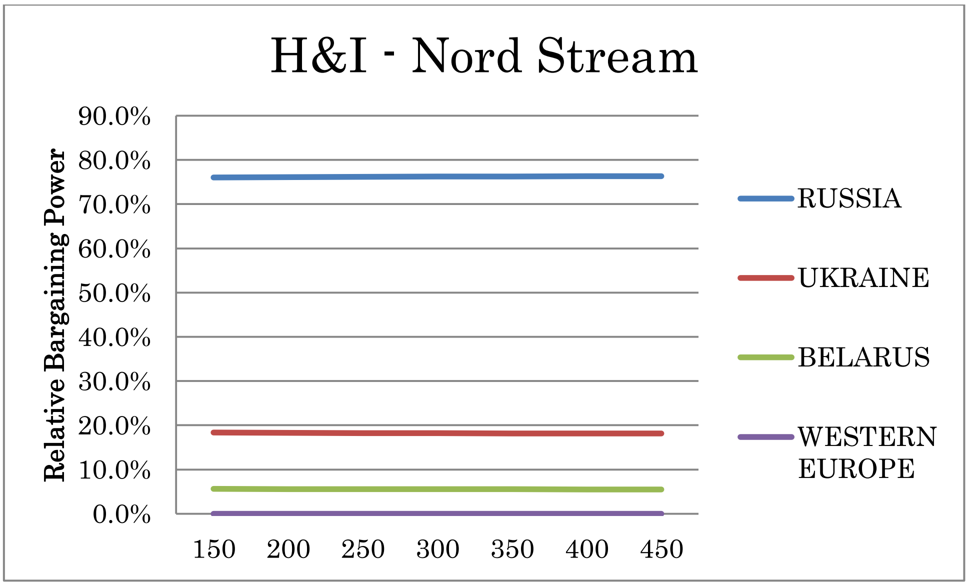


Figure 35 Sensitivity Analysis for H&I Nord Stream

(ii) NH-Style LBFN

The results of NH-style LBFN are very different from that of the two other models. Russia's Relative Bargaining Power increased only by 3.5%, Ukraine's decreased by 11.3%, Belarus lost 3.3%, and Western Europe gained 11.1%. One might argue that with Russia's gain in Relative Bargaining Power being so small, Russia would not construct a costly pipeline like the *Nord Stream*. This is partially true, because questions around the economic viability of the *Nord Stream* plan were among the most important that led to a delay in the implementation of the project. Only after the rapid spike in oil prices and the consequent rise in natural gas prices did analysts start to feel positively about the economic viability of this megaproject (Chyong et al 2010).

Therefore, the forecasts of this model seem to be more in line with reality than the calculations by Hubert and Ikonnikova (2011) or the HI-based LBFN, because if it was apparent to Russia that it would gain between 22.6% and 26.1% in Relative Bargaining Power, robbing a maximum of 17.1% from Ukraine and 9.1% from Belarus, then there would be no reason why Russia would not immediately take all measures necessary to construct the *Nord Stream* pipeline, and critics would no longer raise concerns about its economic viability.

The sensitivity analysis shown in Figure 36 also provides an additional perspective. The Nord Stream would greatly empower Russia in terms of Relative Bargaining Power, regardless of changes in natural gas prices. Russia is the strongest player, topping the runner-up, Ukraine, by over 10%. Thus, although Nord Stream is a challenge from an economic point of view, the geopolitical implications are apparent.

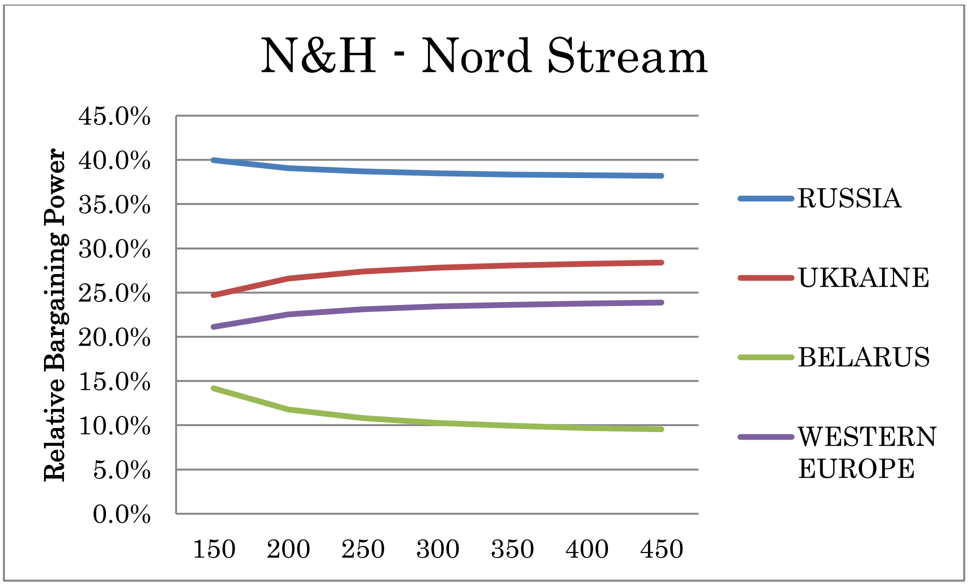
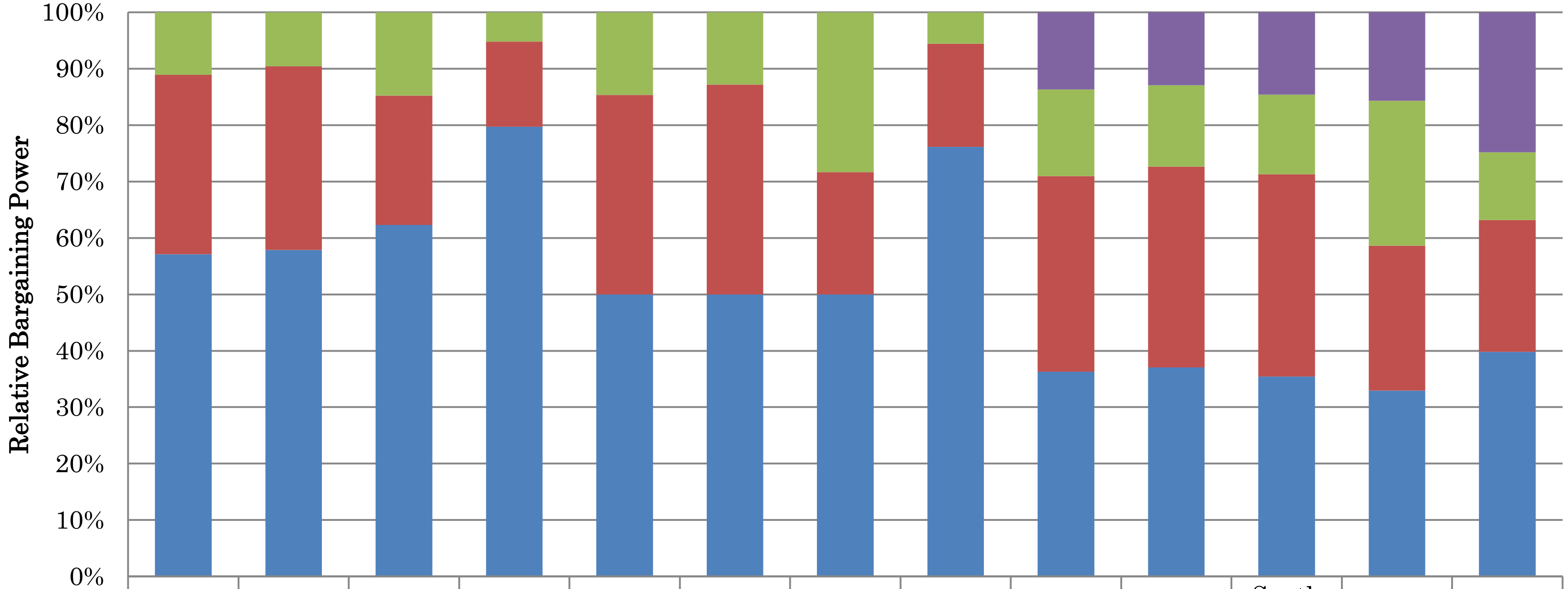


Figure 36 Sensitivity Analysis for N&H Nord Stream

Therefore, it can be cautiously concluded that it was this subtleness in the gains for Russia that made Nord Stream a difficult decision. Nord Stream was more of a reactive judgment to mitigate the risks instigated by the Russian-Ukrainian Gas Conflicts from 2005-2009, as will be explained in the next chapter. The necessity of bypassing Ukraine grew each year, and the other potential candidate, Belarus, was not trustworthy enough. Therefore, it can be speculated that both Russia and Western Europe decided that it was in their best mutual interest to bypass Ukraine altogether.

A holistic representation of the Relative Bargaining Powers of each player in each scenario are at the price of $200/tcm are shown in Figure 37 below.



	Status Quo (H&I2011)	South Upgrade (H&I2011)	Yamal (H&I2011)	Nord Stream (H&I2011)	Status Quo (HI-Style LBFN)	South Upgrade (HI-Style LBFN)	Yamal (HI-Style LBFN)	Nord Stream (HI-Style LBFN)	Status Quo (NH-Style LBFN)	South Upgrade, U Buys (NH-Style LBFN)	South Upgrade, WE Buys (NH-Style LBFN)	Yamal, WE Buys (NH-Style LBFN)	Nord Stream (NH-Style LBFN)
WE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	13.7%	12.9%	14.6%	15.7%	24.8%
B	11.10%	9.60%	14.30%	5.20%	14.7%	12.8%	28.3%	5.6%	15.4%	14.4%	14.2%	25.7%	12.0%
U	31.80%	32.50%	22.20%	15.10%	35.3%	37.2%	21.7%	18.3%	34.6%	35.6%	35.8%	25.7%	23.4%
R	57.10%	57.80%	60.30%	79.70%	50.0%	50.0%	50.0%	76.1%	36.3%	37.1%	35.4%	32.9%	39.8%

Figure 37 Relative Bargaining Power in All Models and All Scenarios

9 Empirical Evidence

In order to make an assessment into the explanatory power of the model as well as to draw implications from the results of the Network Game Analyses, a search was made for empirical evidence that signifies that the predictions of the model are in line with what happened in the real relationship among these countries involved in the trade of natural gas. More specifically, two empirical approaches were employed: a quantitative approach and a qualitative approach. The former is a search for a correlation between the Relative Bargaining Power and other indices, such as the relative price of natural gas for the players involved in the trade of natural gas.

Before the results of the analyses are explained, two premises must be introduced. The first is the credibility of pipeline plans, and the second is the degree to which natural gas prices are important to the players involved. Explanations of these premises are made in the two following sections, followed by the qualitative and quantitative analyses.

9.1 Credibility, Feasibility and Viability

In both approaches, it is important to consider the fact that natural gas pipeline plans become a credible strategic element only in the case that there is a shared perception that the pipeline plan is feasible both economically and politically. Such perceptions regarding the pipeline plans as credible threats rather than mere bluff are formulated as certain milestones are met, or as the external conditions ripen. In other words, it is natural to expect that the credibility and feasibility of a proposed pipeline plan would be a key factor in the negotiations. And thus, the Relative Bargaining Power of the four players can be expected to change as the credibility, feasibility and viability of Nord Stream increases. These three terms will be further defined as below.

The feasibility of a pipeline plan is defined as the extent to which the technical, political and environmental obstacles may be overcome. The plan would not be feasible if the technical hurdle is too high. In the early years after the collapse of the Soviet Union, Russia did not have the technology to build a deep-water pipeline like the Nord Stream and such plan would have been dismissed as bluff. If the relationship between Russia and Western European countries was one of hostility such as in the later years of the Soviet Era after the invasion of Afghanistan and the consequent American measures to sanction the Soviet Union, a direct connection between Russia and Germany would have been disregarded as unfeasible. If the environmental impact assessments concluded with results that clearly showed a full-scaled destruction of the Baltic environment as a result of the Nord Stream construction, the plan may have been disapproved by the Scandinavian and Baltic nations. In fact, the Scandinavian onshore plan that Gazprom had once considered was omitted for the sake of environmental protection (Nord Stream AG 2007). Nord Stream was regarded as a feasible option only after Gazprom became financially sound enough to procure deep-water engineering technology from Western European engineering firms, politically amiable with its European neighbors, and approved by Scandinavian and Baltic nations from an environmental perspective.

Viability here is defined here mainly as “Economic viability”, or the extent to which the pipeline plan may be profitable, or its ability to break even at minimum.

Although natural gas business may be operated by essentially state-owned or state-controlled entities in countries like Russia (Gazprom), Ukraine (Naftogaz) and Belarus (Beltransgaz), pipeline plans are financed with private sources, and consortiums are formed among privately held companies. Therefore, a pipeline plan must be economically viable for it to receive the proper financing. For example, Nord Stream was disregarded as an economically unviable plan in the earlier years of its inception because natural gas prices were far cheaper than they are today, and it would have taken decades for a multi-billion dollar project like Nord Stream to break even when natural gas prices are a mere $100 per thousand cubic meters.

The credibility of a pipeline plan is defined as the perceived likelihood that a pipeline plan would be implemented and fully operational in a strategically meaningful period of time. For a pipeline plan to be credible, it must be both feasible and viable. Therefore, for a pipeline plan to be regarded with credibility, it must clear the abovementioned definitions of feasibility and viability, and the key decision maker must be perceived to be fully determined to follow through with the plan.

As abovementioned, Nord Stream, in its initial phases, may not have been perceived as a serious or credible threat. As mentioned in Chapter 6, when the ambitious deep-water pipeline plans were first announced in 1997, Gazprom had neither the technical nor financial capabilities to bring the plan to life. Milestones such as the joint feasibility study or Gazprom's board approval of the project implementation schedule may not have sufficed because the former is a prerequisite that does not involve much cost, and the latter is a reversible, unilateral move by Russia.

Examples of significant milestones may include the basic agreements on construction or the beginning of the onshore construction, since with these procedures, non-negligible and nonreversible costs accrue. It can be expected that such milestones contributed to a change in the perceptions of the strategic players.

Thus, while some events only added a subtle, incremental step in the "perceived likelihood" that the Nord Stream pipeline would become a viable option, other events such as the actual construction significantly increases the perceived likelihood of the plan. The process may be envisioned as a continuous function of time, and the Relative Bargaining Power changes as the perception of plan's likelihood changes, as shown in Figure 38 below.

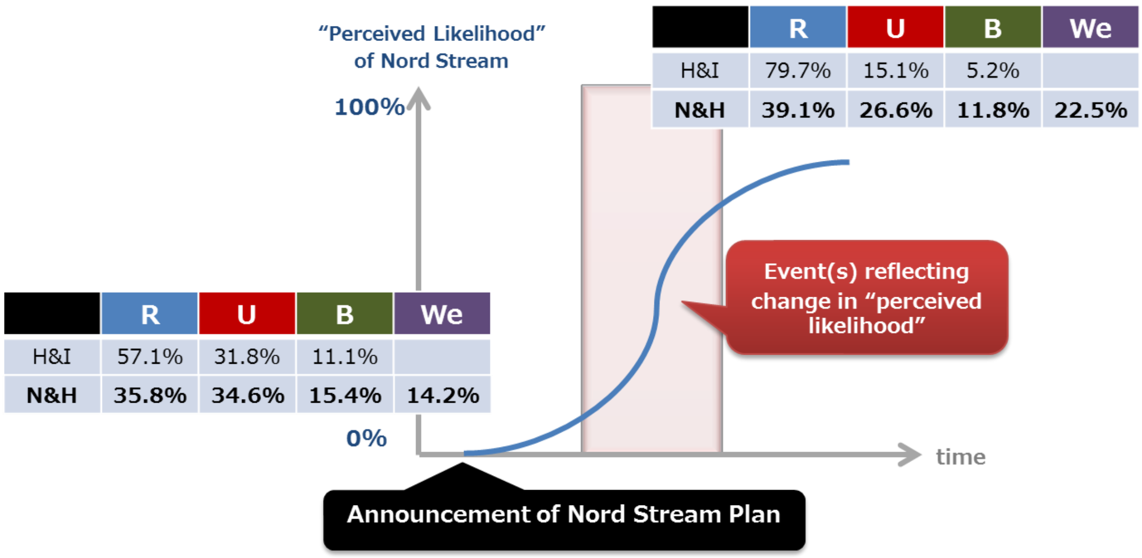


Figure 38 "Perceived Likelihood" of the Nord Stream Plan

In Figure 38, the Relative Bargaining Power of the players begins with Russia having 35.8%, Ukraine with 34.6%, Belarus with 15.4% and Western Europe with 14.2%. When Nord Stream is completed and fully operational, Russia's Relative

Bargaining Power is forecasted to increase to 39.1% and Western Europe increases to 22.5%, whereas Ukraine decreases to 26.6% and Belarus decreases to 11.8%, If Nord Stream Pipeline was built overnight, the change in Relative Bargaining Power would be an immediate shift, but since construction of the pipeline is a gradual and incremental process, the Relative Bargaining Power also shifts gradually and incrementally. Yet, the pipeline need not be fully completed and operational for the Relative Bargaining Power to reach the values forecasted by the Nord Stream Scenario, because once the players have a perception that the Nord Stream Pipeline Plan is indeed one of full credibility, negotiations would take place based on that premise.

9.2 The Importance of Natural Gas Prices

This thesis has been designed on the premise that natural gas prices are a crucial factor for the players involved, and this section assesses the approximate degree to which gas prices are important to the players involved.

Ukraine and Belarus share a similar situation, in which the relatively weak economies are heavily dependent on natural gas as both a source of energy and a source of revenue through transit fees. Ukraine's Gross Domestic Product is approximately \$350 billion, and Belarus's Gross Domestic Product is approximately \$55 billion (IMF 2011). For economies of these sizes, sharp increases in natural gas prices may have a profound effect.

Table 5 below is an estimate of the total cost of Russian natural gas for these two countries. A rough assumption is made that on average per annum, Belarus imported about 20 billion cubic meters, or almost all of its domestic demand for natural gas from

Russia, and Ukraine imported 50 billion cubic meters, or about two-thirds of its domestic demand for natural gas from Russia. The total cost for Russian natural gas in these countries for the years in which prices were maintained in the vicinity of Russian domestic prices (from years 2000 to 2005) comes to about $687 - 933 million for Belarus, and about $2 - $2.5 billion for Ukraine.

When price negotiations with Russia concluded with a two-fold price rise in 2007, the cost of Russian natural gas increased by $1 billion for Belarus, and increased by about $2 billion for Ukraine. Considering that the two countries' economy was smaller than the above-mentioned Gross Domestic Products, and the extent to which the two countries' industries relied on relatively low energy prices, such spike in natural gas prices can be expected to have a detrimental effect on their economic wellbeing.

Table 5 Gas Prices and Estimated Total Gas Cost

	Belarus (20 billion cubic meters)		Ukraine (50 billion cubic meters)	
	Gas Price	Total Gas Cost	Gas Price	Total Gas Cost
2000	$34	$687,400,000	$40	$2,000,000,000
2001	$34	$687,400,000	$40	$2,000,000,000
2002	$34	$687,400,000	$40	$2,000,000,000
2003	$34	$687,400,000	$40	$2,000,000,000
2004	$47	$933,600,000	$50	$2,500,000,000
2005	$47	$933,600,000	$50	$2,500,000,000
2006	$47	$933,600,000	$95	$4,750,000,000
2007	$100	$2,000,000,000	$130	$6,500,000,000
2008	$128	$2,560,000,000	$180	$8,975,000,000
2009	$150	$3,000,000,000	$260	$12,987,500,000
2010	$171	$3,420,000,000	$307	$15,350,000,000
2011	$247	$4,940,000,000	$400	$20,000,000,000
2012	$166	$3,312,000,000	$421	$21,025,000,000

When natural gas prices reached a peak for Belarus in 2011, cost for natural gas in Belarus had reached approximately $5 billion, and when gas prices reached a peak for Ukraine in 2012, estimated cost of Russian natural gas reached about $21 billion. For Belarus, this is about 10% of its Gross Domestic Product, and for Ukraine, this amounts to about 7% of its Gross Domestic Product. Even if the two countries attempted to subsidize gas with government finance, this would be highly difficult given that Belarus's annual expenditure as of 2011 was $22.3 billion and Ukraine's annual expenditure as of 2011 was $56.39 billion (CIA World Fact Book 2011). Therefore, natural gas pricing is a matter of vital importance for Ukraine and Belarus, to an extent incomparable with that of the wealthy Western European nations, where in most cases the cost of natural gas imports amount to far less than 1% of their Gross Domestic Product.

Therefore, countries like Ukraine and Belarus attempted to utilize their strategic position to negotiate prices with Russia, so as to protect its own economic well-being. From Russia's perspective, the Western European natural gas price index is the "fair market price", and ultimately, relations with Ukraine and Belarus are truly "according to international norms and standards" only if prices in these two countries reach European standards. Although this is a normative reason for Russia's attempts to increase gas prices for former Soviet Union countries, there is actually a much more vital reason behind Russia's strong, sometimes oppressive demand for increased prices.

In an article in Ria Novosti, it has been reported that President Vladimir Putin had said at the annual meeting of the Valdai Discussion Club that "fifty percent of our budget revenue comes from oil and gas sales. But if we take it as a percentage of our overall GDP, the oil-and-gas sector revenue is declining. And we plan for this revenue to drop even further against GDP" (Ria Novosti, October 26th, 2012). The fact that the Russian head of state has admitted that the country is reliant on oil and gas sales for more than half of its budget is shocking enough, but experts claim that Putin has "played down" the dependence. An article by Russia and India Report writes "according to official data, commodities contribute around 60 percent of the federal budget; in reality, that number is closer to 75–80 percent as much of the service sector depends on money from oil and gas" (Russia and India Report, October 26th, 2012).

Thus, gas prices are clearly a crucial factor for Russia's fiscal well-being, and therefore, the bargaining between Russia and the two transit countries have been a fierce and constant battle over Russia's determination to raise prices to European standards, and the transit countries' vehement attempt to maintain the lowest price possible.

Natural gas prices in Europe, on the other hand, have been based on an oil-indexed reference pricing mechanism, and the trade of natural gas between Western European nations and Russia has also been based on a similar reference pricing mechanism (Shiobara 2007). The exact formula of the mechanism is not publicly known, but as seen in Figure 40, there is a clear correlation between the price of Russian natural gas at the German border and crude oil prices. Roughly speaking, natural gas prices at the German border have followed crude oil prices with a 4-6 month lag, as seen most clearly in the price spikes in late 2008.

Therefore, although Western Europe is treated as a strategic player in this thesis, it is not a strategic price bargainer in the same sense that Ukraine and Belarus are. Western Europe essentially attempts to evade the political hassle that would arise from price negotiations. Being on average far more affluent than Russia or the transit countries, it can be speculated that Western Europe's primary strategic focus had been on the stability of natural gas supply rather than purchase at lower prices. Therefore, although Western Europe is not a strategic player in the sense of price bargaining, it is in Western Europe's interest to weaken the Relative Bargaining Power of Ukraine and Belarus so as to confiscate the power that these countries have exerted by bargaining with Russia over debt payment and gas prices, consequently leading to the Russian-Ukrainian and Russian-Belarusian gas conflicts that jeopardized Western Europe's energy security.

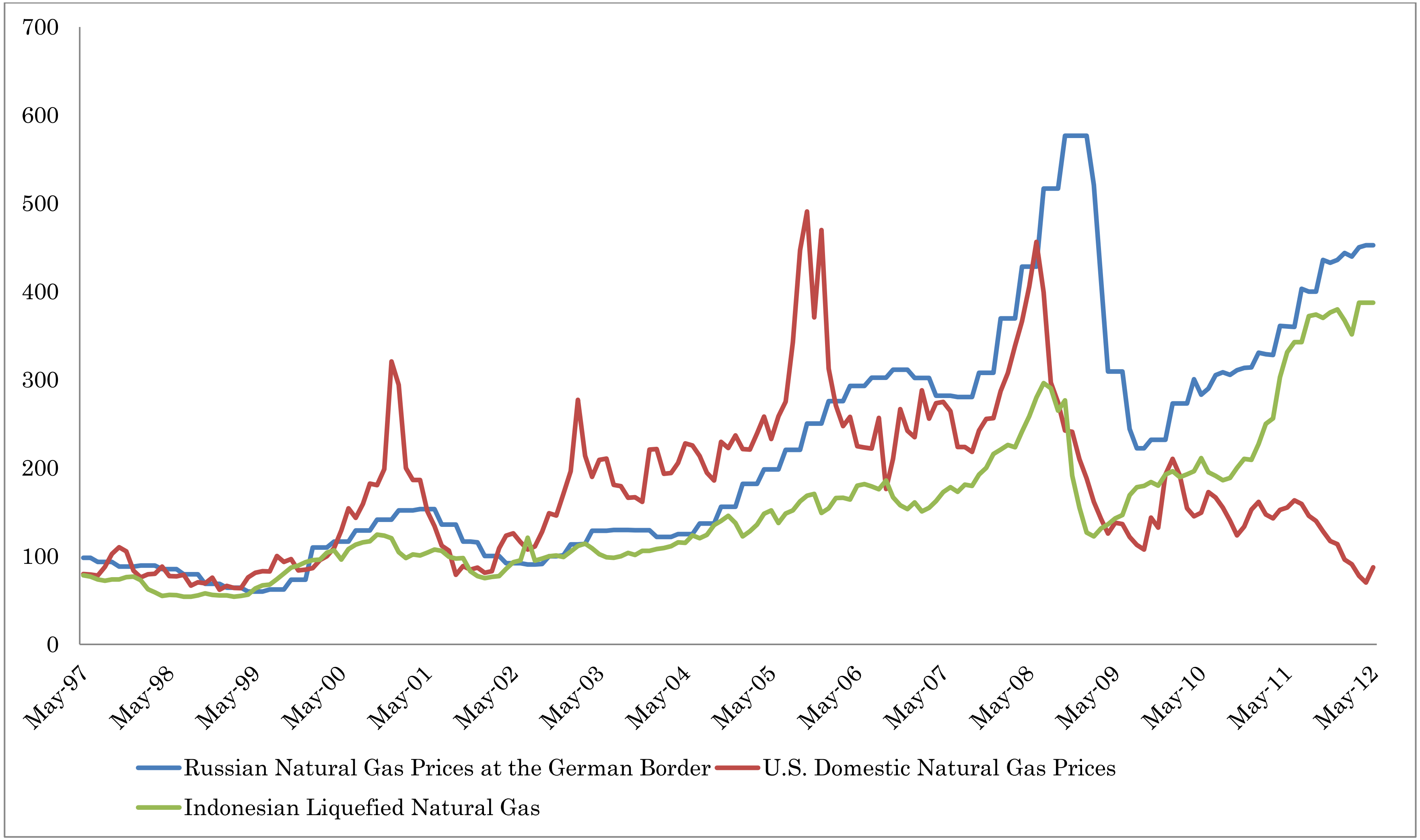


Figure 9 Regional Natural Gas Price Indices (IMF)

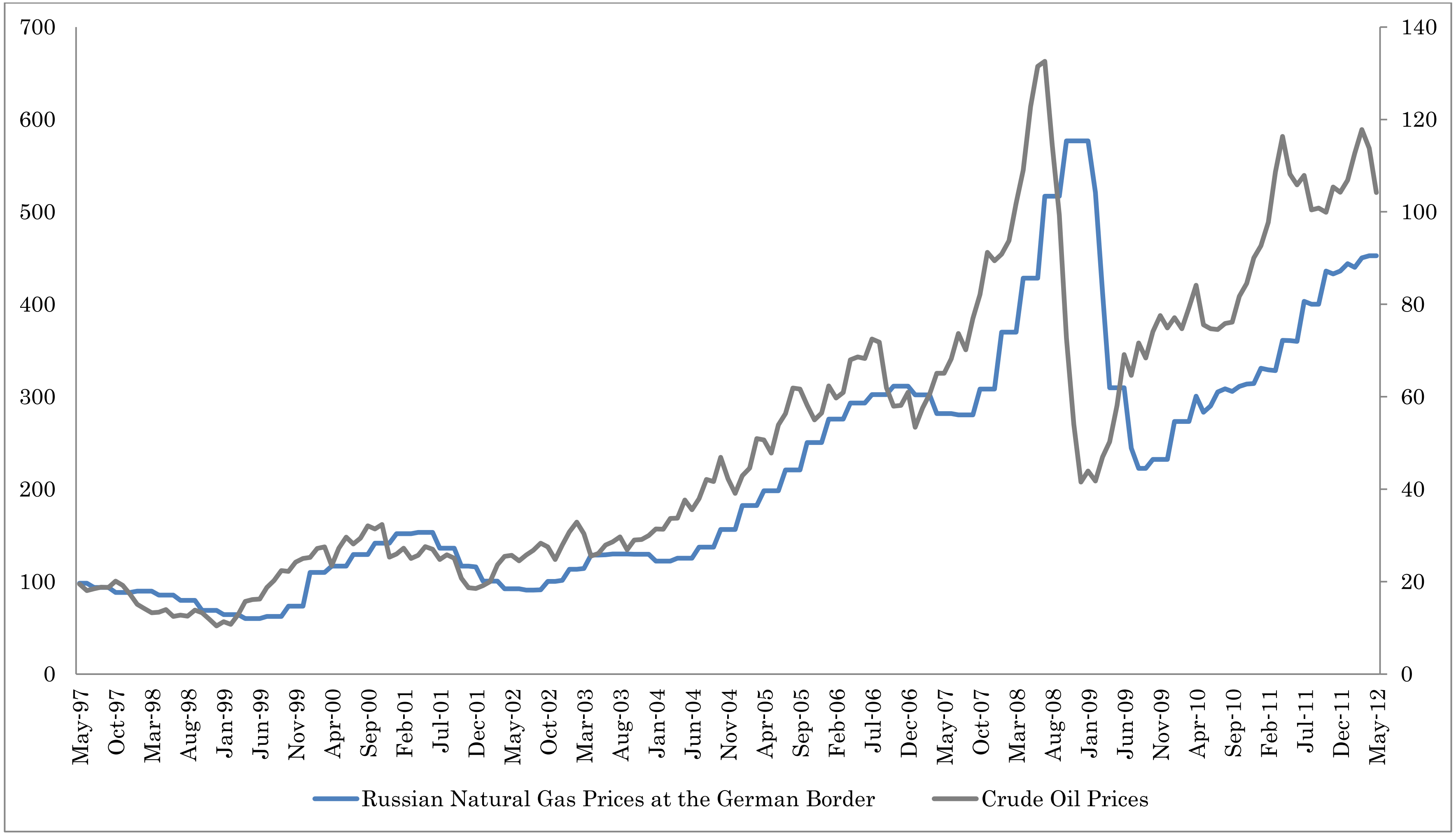


Figure 40 Comparison of Western European Gas Prices and Crude Oil Prices (IMF)

9.3 Qualitative Approach

The first approach employed is a qualitative and descriptive approach, in which actual events involving the natural gas pipelines (e.g. construction of pipelines, negotiations between Gazprom and importing countries about prices or ownership) are attributed to the change in Relative Bargaining Power of the countries involved. In the following sections, the history of the case is revisited in phases, based on key events that occurred at that time. A graph showing the natural gas prices for each player between the years 2000 to 2012 are shown with the phases indicated by a red highlight.

Phase 1: Before 2003 (Figure 41)

The first announcement of the Nord Stream Pipeline was in 1997, and until 2003, there was no publicly known gas price negotiation between Russia and the two transit countries: Ukraine and Belarus (Pirani 2009). Thus, although 6 years had elapsed since the first announcement, signs of shifting Relative Bargaining Power are not apparent.

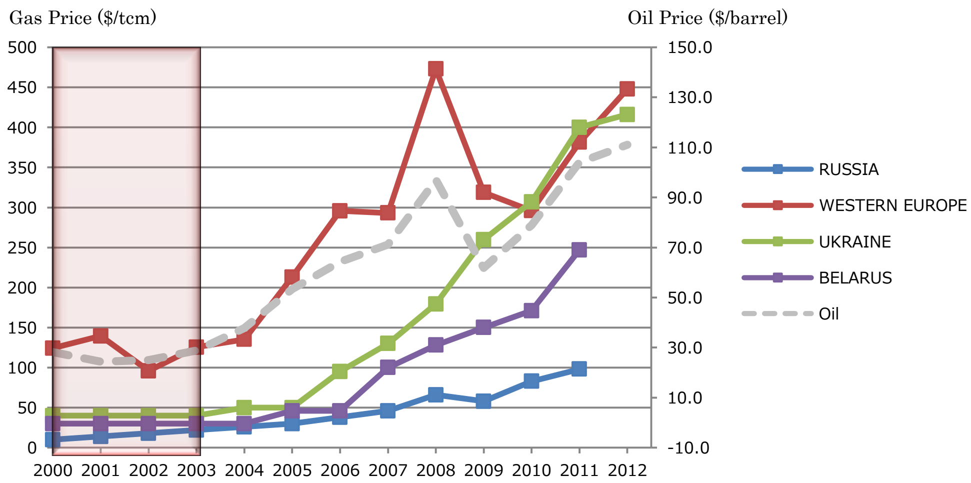


Figure 41 Gas Prices (Before 2003 highlighted)

(Graph Created by Author based on Data from Victor et al 2006 and Newspaper Articles)

Phase 2: 2003 – 2004 (Figure 42)

It was in 2003 that Russia first threatened Belarus to raise prices from the previous price of $34.4 per thousand cubic meters to $50 per thousand cubic meters. The condition that Russia would keep the low price of $34.4 per thousand cubic meters was for Belarus to give up half of the shares of its domestic natural gas supply network entity, Beltransgaz. These were the events that instigated the Russian-Belarusian gas crisis of 2004 (Pirani 2009).

Although Russia's demand was a strategic move against Belarus, it is unlikely that a shift in Relative Bargaining Power as a result of Nord Stream was Russia's rationale to exert pressure. The events regarding Nord Stream that happened before 2004 were merely route surveys, feasibility studies and internal decision making within Gazprom (Gazprom AG 2006), and there was no public commitment by the entities that would bind them to a prompt construction of the pipeline plan. Western European prices were volatile because of the oil-based formula, but prices were fairly stable during the years 1999-2003 ($124.3 per thousand cubic meters in 1999, and $135.2 per thousand cubic meters in 2003).

Therefore, the pressure exerted by Russia to raise Belarusian gas prices can be interpreted more as a measure to match the price for Belarus with that of Ukraine. Ukraine was paying $40 per thousand cubic meters in the years before 2003, and the price was raised to $50 per thousand cubic meters in 2003. Ukraine and Belarus, as modeled in this thesis, are in an almost identical strategic position with respect to Russia (except for the fact that a far larger quantity of gas is transported through Ukraine). There would not be any rationale in charging higher prices for Ukraine than Belarus, but the first Russian-Belarusian Gas Conflict of 2003 flamed up. The two parties finally agreed to a new price of $46.7 per thousand cubic meters.

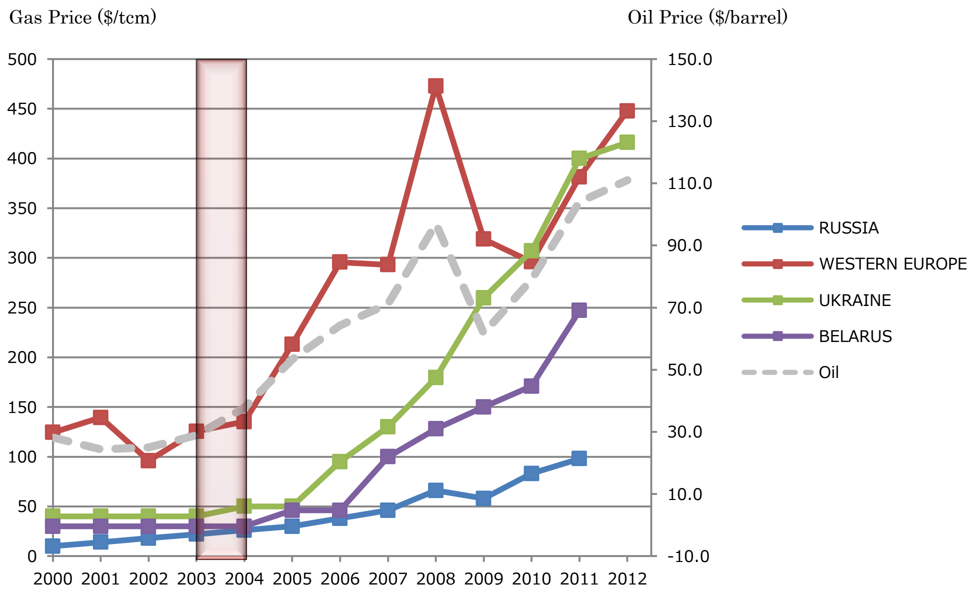


Figure 42 Gas Prices (2003-2004 highlighted)

(Graph Created by Author based on Data from Victor et al 2006 and Newspaper Articles)

Phase 3: 2004 – 2005 (Figure 43)

The demand for a major price increase was conveyed to Ukraine for the first time in March 2005. The increase was a threefold increase to $160 per thousand cubic meters, and it was the first sign of Russia's intention to charge prices that were in line with Western European market prices rather than with Russian domestic prices. By this time, global energy prices were on the rise, and Western European market prices had spiked up to $212.9 per thousand cubic meters. Gazprom demanded a price increase to $160 per thousand cubic meters, and Ukraine's decline led to the first Russian-Ukrainian Gas Conflict of the 21st century (as previously mentioned, there were several, less major conflicts between Russia and Ukraine in the 1990s).

The Russian-Ukrainian Gas Dispute of 2005 was a significant event in that it brought strategic thought into the minds of the players involved. Western European nations perceived Russia as an unreliable source of energy and Ukraine as an unreliable transit country. Widespread concern was instigated over the issue of energy security in the European Union.

Russia and Ukraine both felt concern that if the Western European market decided to diversify its energy import portfolio (e.g. import from other countries such as Qatar, or to divert away from natural gas as a resource and move further to nuclear or renewable energy), both Russia and Ukraine would lose the bargaining power that they have long enjoyed. In that sense, Russia and Ukraine, which were the conflicting parties in the gas crisis, actually shared a common motivation that exports to Western Europe must sustain, and that a shift in Europe away from natural gas would not be in the interest of neither Russia nor Ukraine.

Yet, an even more favorable strategy for Russia was to bypass Ukraine altogether while sustaining gas exports to the Western European markets and thus, the Nord Stream project was accelerated. The environmental impact assessment, which is a crucial step in convincing the countries whose waters through which the pipeline would pass and affect, was sent to all stakeholders including Finland, Sweden, Denmark, Germany, Poland, Latvia, Lithuania and Estonia (Gazprom AG 2006). If these countries did not consent to the plan, Nord Stream could not have been built according to the announced routes. Therefore, submission of the environmental impact assessment applications could potentially have been a double-edged sword, because if the results were negative and one or more of the countries involved rejected the pipeline plan, the plan would have lost most of the credibility that it had gained to date. Therefore, the application can be understood as Gazprom's determination to follow through with the Nord Stream Pipeline.

It can be expected that by this time, Nord Stream had become a probable and credible plan. The pipeline plan may not have brought Russia to its maximum Relative Bargaining Power because the exact timing that the pipeline would be completed was unknown, and the issue of economic viability awaited clearance for Russia to put its full weight behind the plan, but Nord Stream was no longer a bluff or fantasy, and it is natural to expect Russia to show signs of its newly acquired Relative Bargaining Power. An example might be Russia's stronger posture towards Belarus in late 2006. This can be interpreted from two perspectives.

The first interpretation is that although Nord Stream was originally intended as a plan to bypass Ukraine, the fact that Belarus is in the same, if not weaker, strategic position that Ukraine is in (*i.e.* transit player between Russia and Western Europe that relies heavily on Russia for domestic gas demands), and therefore, Russia perceived Belarus as being at the verge of being completely robbed of its Relative Bargaining Power. Therefore, Russia would no longer need to subsidize Belarus with lower gas prices. In fact, Russia demanded that Belarus would begin to pay market-oriented prices from 2004, which is estimated at around three times that of the pre-2004 prices.

The second interpretation is that Russia's primary strategy was to exert pressure on Ukraine, and that the pressure exerted on Belarus was a tactic for Russia to exert further pressure on its true target. As mentioned in Chapter 5, the majority of gas exported from Russia to Western Europe passes through the Ukrainian pipeline, and therefore, Ukraine is a far more important transit country than Belarus. It had been Russia's strong desire to regain control over the Ukrainian section of the transboundary pipeline, as it had in the Soviet Era. If Russia (Gazprom, to be more precise) gained full control over the Ukrainian section of the pipeline, then the costly Nord Stream project would become redundant and obsolete, because full control over the Ukrainian section is synonymous to a large-scaled direct connection between Russia and Western Europe.

Therefore, Russia had, from time to time, offered gas discounts and debt cancellations for Ukraine under the condition that Ukraine would sell part of its stake in the national gas utility, Naftogaz (Shiobara 2007). But Ukraine strongly opposed such deal, knowing that it would not only lead to the loss of its strategic bargaining position between Russia and Europe, but also to the loss of rent it had been receiving due to this position, and most importantly, to the forfeiture of its own energy independence.

It was under such circumstances that Gazprom and Belarus signed a protocol stipulating that Gazprom would acquire half of the shares of Beltransgaz, the Naftogaz-equivalent in Belarus. $2.5 billion was paid for these shares, and the gas prices for 2007 were set at a non-market price of $100 per thousand cubic meters (Victor et al 2006). It may have been Russia's intention to gain control over the Belarusian section of the pipeline network in order to strengthen its bargaining position over Belarus, but more importantly, it may have been a signal to Ukraine that there would be significant benefit in giving up a large portion of the control over domestic gas utilities. With the transaction to sell half of Beltransgaz shares to Gazprom, Belarus entered into an agreement with Gazprom to receive gas from 2007-2011 at a price formula that would be calculated based on market prices, but at a considerably lower proportion.

The price changes for Ukraine went through somewhat of a similar history as that of Belarus. Ukraine's prices increased for the first time in 2004 to approximately $50 per thousand cubic meters, from the previous $40 per thousand cubic meters (Shiobara 2007). This increase was significant in the sense that prices changed whereas they were fixed until then, but given that there was a price increase in Russian domestic gas, it was natural to expect that exported gas prices would also increase.

A larger shock came when in March 2005 Gazprom informed Ukraine that it would increase gas prices to "market levels" by 2006 (Stern 2006). Since Gazprom at first demanded a price of $160 per thousand cubic meters, and European prices were at around $182.16 as of March 2005, Russia was essentially demanding prices that are almost equal to Western European prices. After serious conflict in early January 2006, the price that gas would be sold to RosUkrEnergo, the intermediary company, was agreed to at $230 per thousand cubic meters.

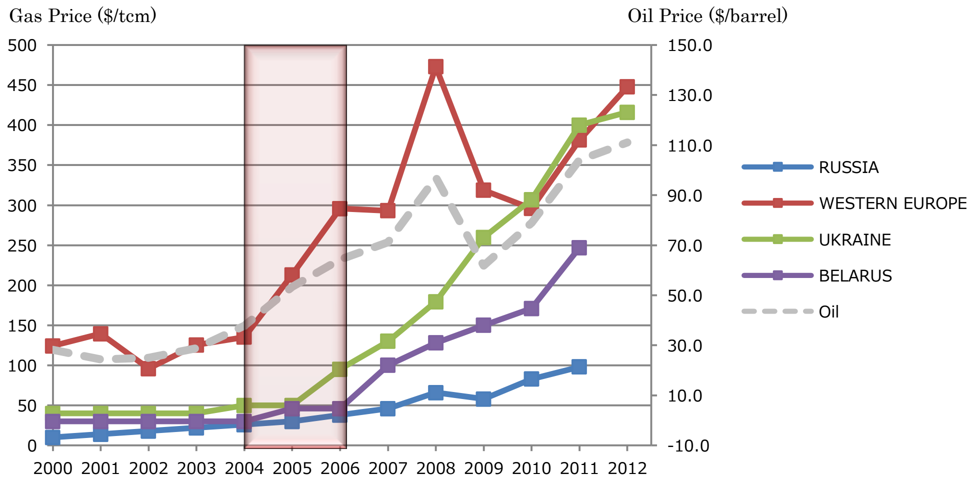


Figure 43 Gas Prices (2004-2006 Highlighted)

(Graph Created by Author based on Data from Victor et al 2006 and Newspaper Articles)

Phase 4: 2007 – Present (Figure 44)

The Russian-Ukrainian Gas Dispute of late 2007 concluded in February 2008, with the price for 2008 being set at $179.5 per thousand cubic meters, significantly lower than the $370 per thousand cubic meters that Western European nations were paying. Again in December 2008, the prices were negotiated, and Gazprom demanded a price increase to $250 per thousand cubic meters. Ukraine offered a maximum of $235 per thousand cubic meters, and as Gazprom declined, the Russian-Ukrainian Gas Dispute of 2009 erupted.

This 2009 gas dispute between Russia and Ukraine was "by far the most serious of its kind" (Pirani 2009). Failure to agree on prices by the end of 2008 led to a cut off on exports from January 1st, and exports to 16 EU member states and Moldova were drastically reduced and cut completely.

Finally on January 20th, deliveries to both Ukraine and other European countries restarted as it was decided that Ukraine would start paying "European market prices starting in 2010, but will receive a price discount for 2009". Prices in 2009 were decided at about $260 per thousand cubic meters, which was slightly lower than what Western European nations paid, but finally in 2010, Ukraine paid gas prices at over $300 per thousand cubic meters, and Ukrainian prices have followed European prices ever since.

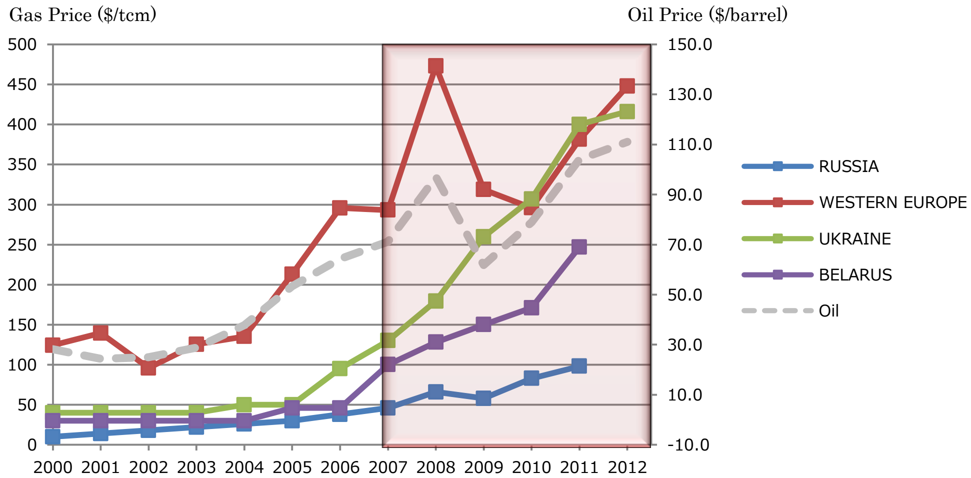


Figure 44 Gas Prices (2007 - 2012 Highlighted)

(Graph Created by Author based on Data from Victor et al 2006 and Newspaper Articles)

Although the price increase seems to be almost linear from year 2005 to 2011, the logic behind the pricing is largely different. The period between 2000 and 2003 was fixed, and the period between 2003 and 2004 was the first ever change in natural gas prices. The period between 2004 and 2005 was stable, but as Russia began to demand European market prices and Ukraine resisted, prices began to rise from 2005 to 2008 at a steady pace. Although the rise was steady, it was not a price formula as in the case of Belarus. Ukraine's steady price increase was the result of gas negotiations and gas conflict with Russia, and Ukraine trying to use its bargaining power to suppress the price increase.

The price increase from 2008 to 2009 was due to the decision after the Russian-Ukrainian Gas Dispute of early 2009 to determine Ukraine's gas prices based on Western European gas prices, but a discount was applied only for 2009. Therefore, if there was no price discount, the price in 2009 should have been at the European level of about $340 per thousand cubic meters. Prices are determined by European market prices after 2010.

For Belarus, the price negotiation in 2006 was when a Europe-based price formula was employed for the years 2007-2011, and for Ukraine, the price negotiation in 2008 led to European-level prices beginning in 2010. In other words, Russia was unable to publicly express its intention to raise gas prices until around 2003, and when it began to exert pressure on both Ukraine and Belarus from 2004, a series of gas disputes erupted with both countries in the period between 2004 and 2006. A semi-permanent agreement for gas price based on European market standards was reached only for the years after 2007. Russia gradually strengthened its position against Ukraine and Belarus, and therefore it may be argued that the progress in the Nord Stream Pipeline, as has been thoroughly explained in this thesis, was one of the decisively powerful rationales for Russia to strengthen its position.

9.4 Quantitative Approach

The second approach taken is a quantitative approach that attempts to supplement and fortify the qualitative assessment conducted in the previous section. If there is a difference in Relative Bargaining Power among players involved in the trade of a certain type of good, one of the most straightforward expectations would be that such difference would be reflected on the price. This may not be true for goods that are abundant in supply or goods that are traded in a fully operable open market, as in the case of the international trade of crude oil. Crude oil is traded at the global scale and any difference in prices among markets would be a target for arbitrage, and thus crude oil price in the international markets is almost uniform around the world.

Natural gas, on the other hand, as explained thoroughly in this thesis, is difficult to store and transport, and thus a global market price does not exist. Several regional price indices (e.g. Europe, United States, and Indonesia) exist and in many cases, prices based on bilateral contracts between exporters and importers. Figure 39 shows the three regional natural gas price indices. The blue line shows Russian natural gas prices at the German border, which is the “Western European” price index used throughout this thesis. The red line shows domestic natural gas prices in the United States, which is by far the largest natural gas consumer in the world (larger than consumption in the entire European Union) and therefore may be treated as a single giant market. The green line shows the price of liquefied natural gas in Indonesia, which is the price index that is used mainly by the Asia-Pacific Region.

Intuitively, if a pipeline plan is regarded as being credible, this would induce a change in the Relative Bargaining Power of the players involved. The moment that the pipeline plan is fully credible, negotiations can be conducted as if the pipeline exists and is operational, and threats can be used with full force. In the case of Nord Stream, Russia’s strategic goals have been to expand exports, to charge market-based prices to former Soviet nations, and to mitigate the risk of a gas crisis so as to maintain its own image as a reliable source of natural gas.

Therefore, it can be expected that an increase in the credibility of the plan would affect the Relative Bargaining Power of the players, and that this change in Relative Bargaining Power would in turn affect the negotiation of trade terms among the countries involved in the trade of natural gas. Specifically, it can be expected that the outcome of price negotiations between Russia and the two transit players would be affected by the change in Relative Bargaining Power.

Figure 45 shows the logarithmic price ratio of Western Europe and the two transit nations, along with an imaginary curve that shows what the change in Relative Bargaining Power between Russia and the two transit countries might look like. The green point in 2000 shows the Relative Bargaining Power Ratio between Ukraine and Russia in the Status Quo Scenario, and the purple point in 2000 shows the Relative Bargaining Power Ratio between Belarus and Russia in the Status Quo Scenario. The corresponding points for year 2011 show the Relative Bargaining Power Ratio for the two countries after the completion of Nord Stream.

The points representing the Status Quo Scenario are plotted in year 2000 because at that time, there was no tangible progress in the Nord Stream pipeline plan, and natural gas prices were fixed for Ukraine and Belarus at levels that closely resembled that of Russia's domestic prices. The points representing the Nord Stream Scenario are plotted in year 2011 because this was the year that gas flowed through Nord Stream for the first time, and Nord Stream became a fully operational pipeline.

The curves between year 2000 and 2011 are mere illustrations of what the change in Relative Bargaining Power might look like. As previously mentioned, it can be intuitively interpreted that as the credibility of Nord Stream increases, the Relative Bargaining Power of the players will continue to change until Nord Stream reaches full credibility, at which time the Relative Bargaining Power of each player will reach the values forecasted by the results in Chapter 8.

Usually, it is expected that pipeline plans proceed as planned, or are at worst suspended, but would rarely recede. Accidents or destruction (e.g. natural disaster, war) may be exceptions, but these phenomena have not occurred in the 15 years since the inception of Nord Stream. The credibility of pipeline plans are also usually expected to increase uniformly, but exceptions may exist if, for example, a financial crisis breaks out and financial commitments are withdrawn. Yet, financial crises eventually subside, and as the global demand for energy continues to increase, it can be expected that the credibility of pipeline plans may stop increasing for a certain period, but would not usually recede. Additionally, many of the procedures in pipeline plans (e.g. approval of construction in Exclusive Economic Zones) are generally irreversible or extremely difficult to reverse without adverse political consequences.

Therefore, in the quantitative analysis conducted below, it is assumed that the credibility of the pipeline plan increases uniformly. Additionally, it is assumed that relatively less important events (e.g. Gazprom's unilateral decisions for the pipeline plan, conducting feasibility studies) only add small increments to the credibility of the plan, and that a single event or a series of important events that symbolize a major development in the plan would dramatically increase the credibility of the plan, Thus, the Logit Function is employed as the model for the credibility of the pipeline plan, and its inverse, the Logistic Function, is interpreted as the consequent change in Relative Bargaining Power.

Figure 45 Logarithmic Price Ratio and Relative Bargaining Power

Logistic Function Model Setup

Let $N = \{1, \dots i, \dots, n\}$ be the set of players, and $p_i(t)$ be the price of natural gas after t years. The Napierian logarithm of the price ratio between Western Europe and the two transit countries is expressed as $q_i(t) = ln\left(\frac{p_{WE}(t)}{p_i(t)}\right)$. The ratio between Western Europe and the two transit countries is used rather than Russia and the transit countries because although negotiations are conducted between Russia and the two transit countries, Russia had always used Western European prices as the basis for "fair market price". The Napierian logarithm is taken in order to allow the change in price ratio to be treated as a sum rather than a product. The model is defined as below.

The Logistic Function-based model for $q_i(t)$ is given as below.

$$q_i(t|M, \alpha_k, \mu_k, s_k) = \alpha_{\mathrm{i,o}} + \sum_{m=1}^{M} \frac{\alpha_{i,m}}{1 + \exp(-\frac{t - \mu_{i,m}}{s_{i,m}})} \tag{11}$$

Here, $\alpha_{i,0}, \dots, \alpha_{i,M}$, $\mu_{i,0}, \dots, \mu_{i,M}$ and $s_{i,0}, \dots, s_{i,M}$ are parameters, and these parameters are estimated with the annual price data in order to grasp the change in price ratio, which is expected to reflect the change in Relative Bargaining Power. The second item is a weighted summation of logistic function, and each of the elements of the logistic function can be interpreted as events that affect the credibility of the Nord Stream Pipeline Plan. The basic form of the logistic function when$\alpha = 1$, $\mu = 0$ and$s = 1$ is shown in Figure 46 below.

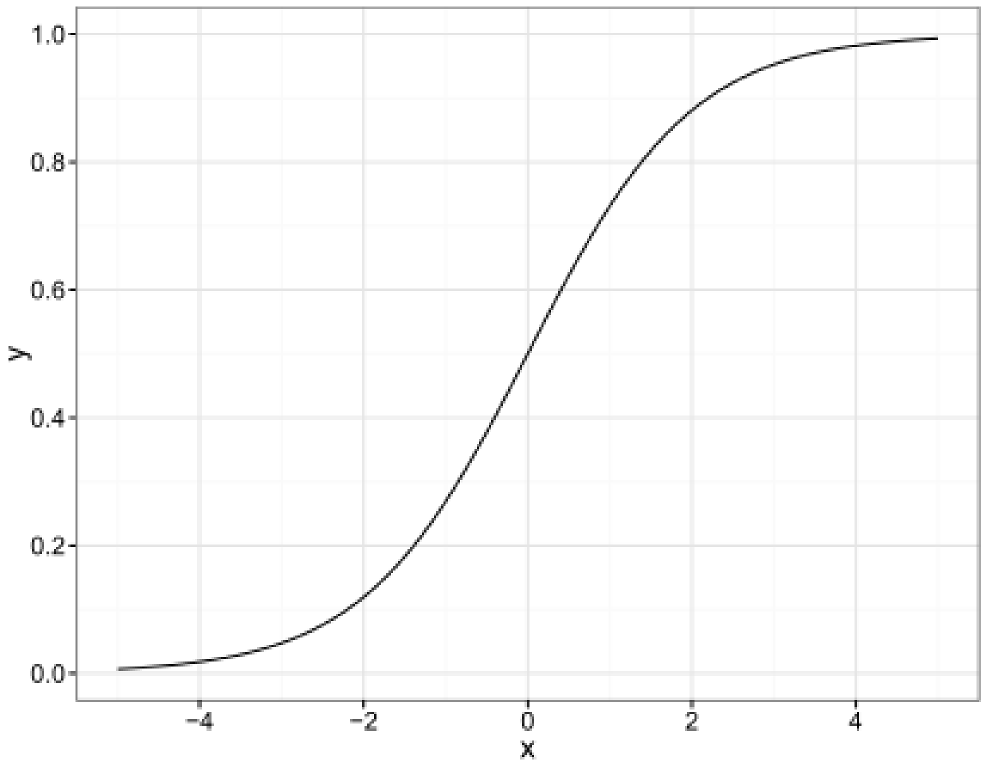


Figure 46 Basic Logistic Function

If several events contribute to the change in the price ratio, then it can be expected that each of these logistic function correspond to such event. And by examining the coefficients$\alpha_{i,m}$ $(m > 1)$, the effect of these functions can be estimated. Each of the parameters defined can be interpreted as explained below.

- $\alpha_{i,0}$: the logarithmic price ratio between Western Europe and the transit country at the status quo
- $\mu_{i,m}$: the center of the S-shaped logistic curve as shown in Figure 46, where the function's value changes most rapidly. In other words, this is the year in which the price ratio between Western Europe and the transit country changed most rapidly, and can therefore be interpreted as the year in which the transit country had to make

the largest compromise in prices. It can further be speculated that the most rapid change in Relative Bargaining Power occurred in the vicinity of this year, but since the outcome of price negotiations may lag behind the change in Relative Bargaining Power, it can intuitively be expected that the change in Relative Bargaining Power from a year or two ago is reflected on the price ratio.

- $s_{i,m}$: the scale of the horizontal axis of the logarithmic function. The larger $s_{i,m}$ is, the S-shaped curve becomes oblong, and therefore the change in price ratio (and thus the change in Relative Bargaining Power) becomes moderate. This can be interpreted as a gradual increase in the credibility of the pipeline plan.
- $\alpha_{i,m}$: the rate of change of the logarithmic price ratio
- M : the number of logistic functions in the model

If increasing the value of M decreases the residual of the model, then it can be said that increasing M would add power of explanation to the model. Letting L be the square error of the model and the actual logarithmic price ratio, L can be defined as below, and the result of the calculation for Ukraine and Belarus are as shown in Table 6.

$$L = \sum_{j}^{n} (x_j - q(j|M, \alpha_k, \mu_k, s_k))^2 \tag{12}$$

Table 6 Least-Squares Analysis of M

M	Ukraine	Belarus
1	0.288	0.393
2	0.288	0.393
3	0.288	0.393

Increasing M does not decrease L, and therefore does not contribute to the power of explanation of the model. Hence, it is concluded that $M = 1$ for the sake of simplicity.

Results of the Logistic Function Model

The results of the logistic function analysis are shown in Table 8. Ukraine's logarithmic price ratio $\alpha_{u,0}$was at 1.105, and then decreased by -1.162 to reach -0.057 in 2011. Belarus's logarithmic price ratio $\alpha_{B,0}$was 1.463 in 2000, and then decreased by 1.049 to 0.424 in 2011.

Table 7 Results of the Logistic Function Analysis

	α_0	α_1	μ_0	s
Ukraine	1.105	-1.162	2008.594	0.496
Belarus	1.463	-1.049	2008.658	0.635

The results of the logistic function analysis are shown in Table 7. Ukraine's logarithmic price ratio $\alpha_{u,0}$was at 1.105, and then decreased by -1.162 to reach -0.057 in 2011. Belarus's logarithmic price ratio $\alpha_{B,0}$was 1.463 in 2000, and then decreased by 1.049 to 0.424 in 2011. $\mu_{i,m}$ is almost identical for both countries at 2008.594 for Ukraine and 2008.659 for Belarus, which shows that the most drastic change in the price ratio occurred in around July to August of 2008. Finally, s is 0.496 for Ukraine and 0.634 for Belarus. The results are shown graphically in Figure 47.

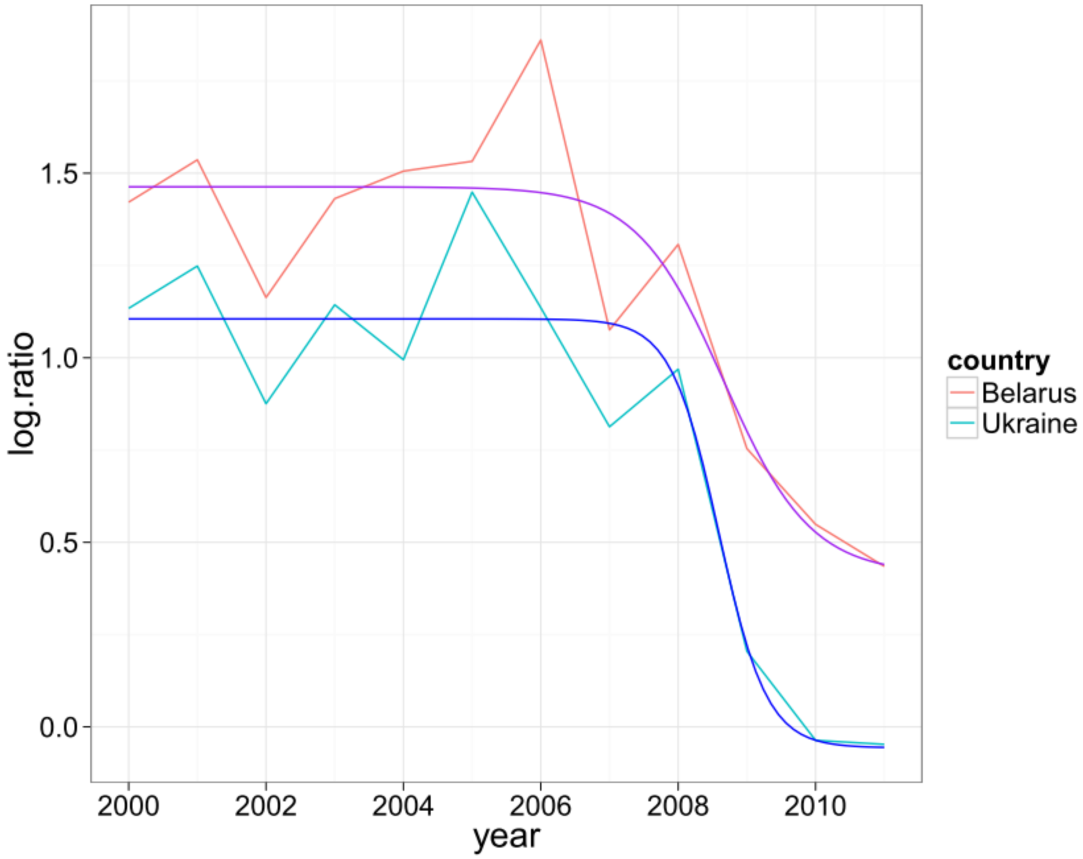


Figure 47 Logistic Function Model of the Logarithmic Price Ratio

By isolating the logistic function from the model, the equation below is obtained. This can be interpreted as the credibility of the Nord Stream Pipeline Plan for the two transit countries.

$$\frac{1}{1 + \exp(-\frac{t - \mu_{i,m}}{s_{i,m}})} \tag{13}$$

As previously mentioned, it can be expected that a change in Relative Bargaining Power may be reflected on the price with a delay, and therefore, if the assumption is that the delay would be 1 year, the resulting graph would look like Figure 48.

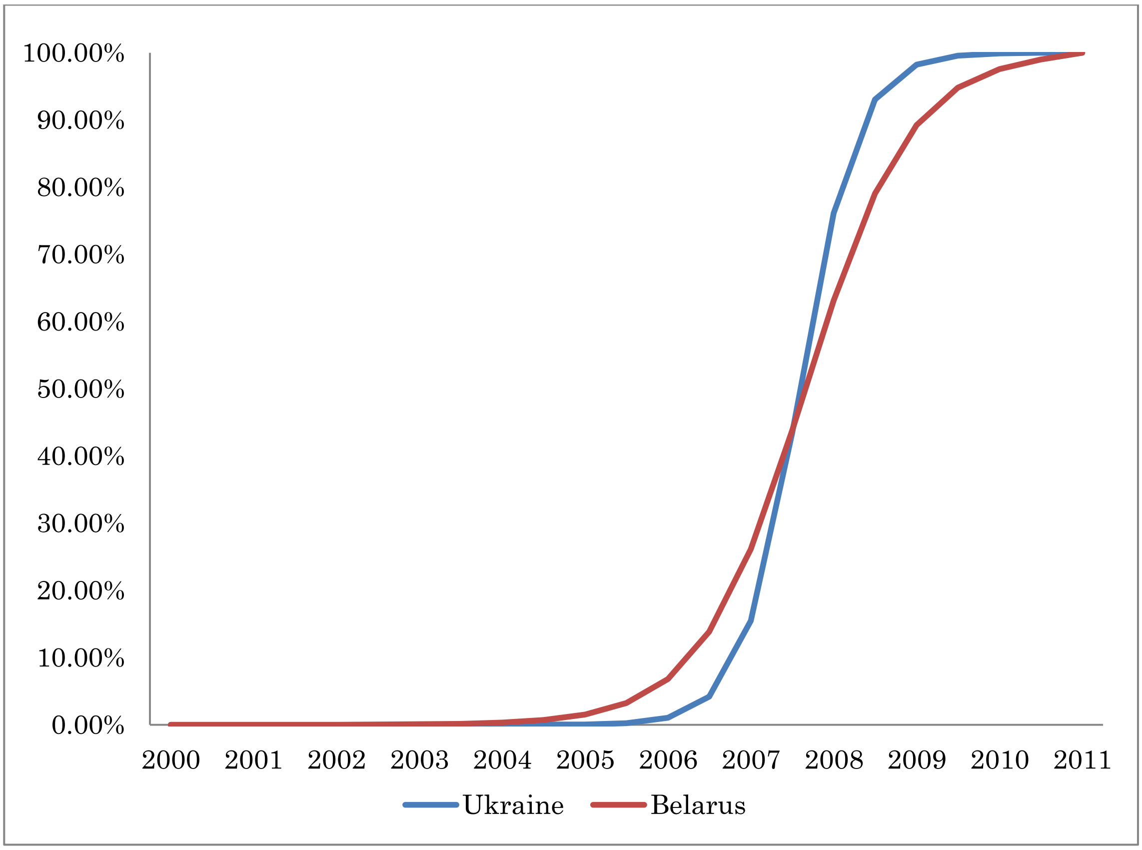


Figure 48 Logistic Function with a 1-year Delay

Interpretation of the Results

The first sign of Russia's increased Relative Bargaining Power is seen in 2005, which coincides with the year in which Russia began the construction of what would later become the Russian onshore section of Nord Stream. There is a slight lag for

Ukraine, but Ukraine experiences a much more rapid increase. This can be interpreted in a two-step process.

The first is that Russia has evaded a two-front bargaining with Ukraine and Belarus. It can be speculated that Russia chose to negotiate with Belarus first, since Belarus is in a far weaker position than Ukraine with less than half of the Relative Bargaining Power of Russia or Ukraine. Ukraine, on the other hand, had a Relative Bargaining Power that is about equal to that of Russia in the Status Quo Scenario, and thus was able to fend off Russia's demand for a price increase. The price increase for Belarus can be seen as a sign from Russia to Ukraine that a deviation from the Soviet Era gas pricing is inevitable even for a Russia-friendly country like Belarus.

Although Belarus was the first to be affected by the increased Relative Bargaining Power of Russia, Belarus experienced a more gradual increase compared to Ukraine. This cannot be explained directly by the logistic model because an important externality happened during this period. Belarus decided to sell half of the shares of Beltransgaz, and received a price discount as compensation for this deal. As repeatedly mentioned in this thesis, it has been a long-cherished dream for Russia to regain control over all of the pipelines that connect its gas fields directly to the European demand centers. In other words, it was in Russia's vital interest to buy shares of Naftogaz so as to gain control over the Ukrainian section of the South Pipeline. The Belarusian section of the pipeline is not nearly as important, but it can be speculated that Russia wanted to show a precedent to Ukraine that forfeiture of its control of Naftogaz would yield considerable benefits. Ukraine declined such pressure from Russia, and consequently, Ukraine's prices increased at a rate much higher than that of Belarus.

Additionally, the quantitative analysis fortifies this thesis's argument that the N&H Game Setup and the Link-based Flexible Network Allocation Rule yield results that better explain the true interactions among natural gas trading countries. As mentioned in Chapter 8, Russia's Relative Bargaining Power at the status quo is forecasted to be over previous work by Hubert and Ikonnikova (2011) forecasts Russia's Relative Bargaining Power at the status quo to be stronger than the runner-up, Ukraine, by over 25%, and the H&I Game Setup in this thesis similarly forecasts that Russia is stronger by approximately 15%.

If these estimates are true, the fact that Russia had been unable to raise prices at a significant level until well after 2005 cannot be explained. Russia's struggle can only be explained by the N&H Game Setup, in which Russia's Relative Bargaining Power is almost at par with that of Ukraine (in fact, the sensitivity analysis in Chapter 8 predicts that Ukraine would become stronger than Russia at gas prices higher than $250/tcm). Russia was able to hold a clearly dominant position over Ukraine only after Nord Stream became a credible plan, at which time Russia's Relative Bargaining Power was surpassed Ukraine by 12.5%. Thus, of the three models explored in this thesis, N&H Game Setup Link-based Flexible Network Allocation Rule is the only model that, in combination with the qualitative and quantitative analyses, is able to consistently explain the geopolitical relationship among these natural gas trading countries.

10 Conclusion

This thesis was able to conduct the analytical procedure and achieve the objectives set forth in Chapter 2. Each of the points is discussed below.

10.1 Application of the Network Game and Link-based Flexible Network Allocation Rule for Additional Modeling Versatility

The model employed in this thesis was based on a Network Game Model defined by graphs and value functions rather than on standard coalitional cooperative games defined by coalitions and characteristic functions. As a result, the following improvements were made to the model in reflecting reality by utilizing the flexibility and versatility of the Network Game Model.

(1) Where existing works using characteristic functions were able to assign value only to coalitions of players (*i.e.* countries), the Network Game approach allowed modeling based on the value accrued from links. The relative allocations defined for these links added an extra dimension of analysis.

(2) Where existing works using characteristic functions could not incorporate both producers (e.g. Russia) and consumers (e.g. Western Europe) as strategic players in the model, the Network Game approach was able to incorporate both by assigning value to the entire network of producers and consumers. Western Europe is indeed a crucial strategic player (e.g. Western Europe is the counterpart for Russia to build the Nord Stream pipeline), and leaving it out would deprive the model of the ability to explain why Western Europe would consent to building

a pipeline like Nord Stream. Additionally, without Western Europe as a subject for comparison, the Relative Bargaining Power of Ukraine and Belarus cannot be fully assessed, because in many cases Russia set prices in negotiation with the transit countries according to Western European market prices. If Ukraine or Belarus is weaker than Western Europe in terms of Relative Bargaining Power, then there is no chance for these transit countries to refuse price increases up to the fair market price.

(3) Where existing works using characteristic functions could not take into consideration the fact that transit countries (e.g. Ukraine, Belarus) are also consumers/importers of natural gas, the network game approach taken was able to define the value of trade between the producer and these transit countries. Thus, the value accrued from the "consumer aspect" of these countries was incorporated into the model. Ukraine is in fact one of the largest importers of Russian natural gas and a player that is strong in terms of Relative Bargaining Power, and the model would be incomplete if these countries were treated as mere transit players.

(4) Where existing works using characteristic functions could not incorporate externalities, the network game approach taken in this research was able to assign separate values for each possible network structure in a computable manner.

10.2 Improvement in the Assessment of the Power Structure

The results of the Network Game Analysis yielded results that are significantly different from the previous work of Hubert and Ikonnikova (2011), and the explanatory power of the forecasts must be discussed. As thoroughly explained in this thesis, Russia had been motivated to achieve two important goals: to raise the price of natural gas and to stabilize its export of natural gas to the Western European demand centers. If Russia was the sole dominant player, there wouldn't be any reason why Russia would not force the importers to take the price that Russia demands. Yet, in reality, it took Russia about five years into the 21st century to begin to incrementally raise prices for Ukraine and Belarus.

The results of Hubert and Ikonnikova (2011) conclude that the Relative Shapley Value (or "Relative Bargaining Power" in this thesis) of Russia is already nearly twice that of Ukraine, and more than five times that of Belarus at the status quo. If these results were true, Russia should have had enough Relative Bargaining Power to impose a price increase on both of these transit countries even before Nord Stream became a credible threat. The main results of this research find that at the status quo, the Relative Bargaining Power of Ukraine was approximately equal to that of Russia, and the sensitivity analysis found that if prices were higher than $250, Ukraine would surpass Russia in Relative Bargaining Power. These results better explain the reason why Russia had been unable to raise the price of natural gas exported to Ukraine until the Nord Stream Pipeline Plan became credible.

The results of Hubert and Ikonnikova (2011) suggest that when Nord Stream is completed and operational, Russia's Relative Bargaining Power would reach five times that of Ukraine and fourteen times that of Belarus. Such bargaining power would be excessive, and it would be expected that the surplus bargaining power would be exerted in a wide array of diplomatic scenes. Western Europe as a strategic player (which it is in this thesis, but not in previous literature) has long tried to evade bestowing too much power to Russia, and would not have consented to the construction of Nord Stream if such forecasts were true. The results of this thesis, on the other hand, forecast that Western Europe would in fact gain Relative Bargaining Power over Russia, while taking bargaining power away from the troublesome transit countries, Ukraine and Belarus. Therefore, it would be intuitive that Nord Stream, a joint project of mutual benefit for Russia and Western Europe, would be implemented based on the forecast of this research.

The forecasts by Hubert and Ikonnikova (2011) lack Western Europe as a strategic player and thus the same analysis cannot be made, but the excessive bargaining power of Russia suggests that the forecasts are in conflict with reality. Thus, it is concluded that the Network Game, Link-based Flexible Network Allocation Rule and the N&H Game Setup has a stronger power of explanation for transboundary natural gas trade through natural gas pipeline networks.

11 Implications, Recommendations and Future Work

11.1 Cause of the Natural Gas Conflicts

Although Russia is sometimes criticized for using its strategic position in natural gas trade for broader political motives, it is unlikely that Russia or any other player involved wished for a series of crises like the ones experienced in the period from 2004 to 2010 between Russia and the two transit countries. With natural gas pipeline networks being planned in many areas of the world, it is important to understand the cause of these conflicts, and identify the key elements that are necessary to evade such serious confrontations in the future.

As noted in this thesis, Western Europe has used a pricing formula that is based on an oil-index and thus has long been a passive price taker rather than an active price bargainer. The analysis by Hubert and Ikonnikova (2011) fails to assess the strategic position of Western Europe, but the results of the analyses conducted in this thesis estimate that Western Europe's Relative Bargaining Power was almost equal to that of Belarus, and about half of Ukraine. Yet, while Ukraine and Belarus bargained fiercely to maintain near-domestic Russian prices, Western Europe's prices fluctuated along crude oil prices. The oil-index was an objective and transparent way to price natural gas based on an already-existing market price index of oil, and a way by which the relatively affluent Western European countries can evade the fierce negotiations that can potentially take place over gas prices, which can in turn create tension with Russia and in the worst case, jeopardize energy security. Using an oil index seemed to be a rational decision to stabilize the supply of natural gas from Russia.

Yet, it can be argued that it was in fact this oil-index and Western Europe's decision to avoid price negotiations that may have indirectly caused the natural gas crises. As mentioned in Chapter 9, natural gas costs are a significant burden for Ukraine and Belarus, and thus these countries are highly sensitive about the price at which they are able to import natural gas. Russia was seeking its long-sought goal to charge higher prices to the former Soviet countries due to its excessive reliance on gas for government revenue. And because Western European prices were perceived to be the fair market price, Russia had repeatedly tried to set Ukrainian and Belarusian prices according to Western European oil-index prices, or at least indexed to Western European gas prices (which are essentially an indirect index to oil prices). In other words, the maximum price that Russia would demand to Ukraine and Belarus was set according to the Western European market prices.

Western Europe's non-strategic posture towards natural gas prices allowed for natural gas prices to skyrocket along with crude oil, and thus the maximum price that Russia would demand to Ukraine and Belarus also skyrocketed. By 2005, natural gas prices were at $212.9 per thousand cubic meters, which was more than twice the price of gas in 2002, which was $96 per thousand cubic meters. This rises in prices were clearly not the result of changes in cost structure for Russia or a sudden change in the supply and demand, but the result of the oil-indexed pricing mechanism.

While this may seem like a fair and transparent way to price gas, natural gas markets are, unlike other commodities that are traded on a global scale, regionally dispersed and difficult to transport and store. It could have been argued that Western European prices were becoming more expensive than both United States and Indonesian price indices. The Indonesian market is predominantly composed of Liquefied Natural Gas, and therefore it can be argued that it makes no sense that the European pipeline gas prices were significantly higher gas sold in the costly LNG form. The United States gas market is also known to be indexed to oil prices, but this is politically justifiable because the United States has domestic oil reserves and gas reserves, and the two commodities are quite obviously a substitute good within the same domestic market. Two independent markets for a substitute good would have created opportunity for arbitrage within the United States, and would have caused problems. The United States has essentially cut off the two markets only with the Shale Revolution proceeding at full scale in very recent years.

Therefore in hindsight, it can be argued that the Western European importers did not have to necessarily use an oil-index pricing mechanism, and could have utilized their strategic position and Relative Bargaining Power to negotiate prices with Russia. Since Western Europe’s Relative Bargaining Power in the status quo was almost equal to that of Belarus, if Western Europe had resisted the oil-index and demanded for lower gas prices, such motion may have protected Belarus from the increased gas prices in 2007. Instead, Western European’s failure to take a strategic bargaining position allowed for prices to rise uncontrollably, which in turn became the rationale for Russia to set the “fair market price” with the transit countries at higher levels, and because the transit countries’ economic conditions did not allow their leadership to tolerate such sharp rise in prices, the fierce bargaining culminated into the notorious gas crises.

Ironically, Western Europe’s wish to stabilize natural gas supplies by abiding by the oil-indexed pricing mechanism resulted in the forfeiture of its Relative Bargaining

Power, and became the indirect cause of the gas crises by effectively stripping Belarus of its Relative Bargaining Power and allowing Russia to exert intolerable price increases onto the transit countries. According to the language employed in this thesis, because Western Europe made no effort to use its Relative Bargaining Power of 14.2% in its relation with Russia, Belarus's 15.4% also became essentially powerless.

If Western Europe had resisted the sharp price increases by arguing that the oil-index pricing mechanism no longer reflected the fair market value of natural gas, Western Europe may have been able to suppress the price spikes. If prices were kept low as a result of Western Europe's bargaining with Russia, then that could have set a lower ceiling for price negotiations between Russia and the transit countries. If Russia's demand for price increases were moderate as a result, then prices may have been more acceptable and the "debt" may have also been payable. The gas conflicts may not have occurred at the level that it had, and therefore, Russia and Western Europe may not have had an incentive that is strong enough to accelerate the Nord Stream Pipeline Plan, which is regarded by some as costly infrastructure to oversupply the market.

11.2 Stability of Natural Gas Networks

Natural gas pipelines are being planned in many areas of the world, very often in areas of geopolitical sensitivity. The TAPI pipeline from Turkmenistan, Afghanistan, Pakistan and India is a representative example. The IPI pipeline from Iran to Pakistan to India is another. Russia's apparent desire to expand to the Far East may materialize into a pipeline that originates in Russia and passes through countries like the People's Republic of China, North Korea, South Korea and Japan. Although such pipeline may seem like a wild fantasy, it is of value to be able to assess the impact that such fantasies may have on the strategic relationship among these countries. The case of Russian natural gas trade with its former Soviet and Western European neighbors provides valuable insight into the assessment of not only existing natural gas pipelines but mere pipeline “plans”, for a credible pipeline plan may have the same strategic power that a real pipeline may have.

The results provided in this thesis call for the need to assess the Relative Bargaining Power of the countries involved, and for each player to be aware of the impact that using (or not using) this bargaining power may have on the relationship among the players involved. Accepting an artificial oil-index that is not based on the supply and demand of natural gas has proven to be capable of generating unnecessary conflict among the players involved. Affluent players in the downstream demand centers must be aware that forfeiture of its own bargaining power over prices may indirectly take bargaining power away from other players along the pipeline.

It is essential for policy makers and decision makers to be aware of their own geopolitical and geostrategic position within the network, and the effect that a change in the actual network or the perception of the network would have on the Relative Bargaining Power. And because Relative Bargaining Power is “relative” by definition, it is also crucial for decision makers to be aware of this relativity so as to be able to predict the absolute outcome that one’s own bargaining may exert on the other players involved. In planning future natural gas pipelines in some of the most geopolitically sensitive areas in the globe, such implications may be of value to the stability of the pipeline network, and the stability of the pipeline network may contribute to the overall stability of the region and the world at large.

11.3 Future Work

Future work in this research may include the following:

(1) Modeling cases of higher complexity, for example with multiple producers, multiple transit players and multiple consumers in order to utilize the full modeling capacity of the Network Game and Link-based Flexible Network Allocation Rule

(2) Modeling cases in a different geographical region

(3) Including recent developments such as LNG exporters and shale gas

(4) Conducting a time-series analysis of Relative Bargaining Power with fluctuating prices considered

Appendix 1: Network Formation Process of Scenarios

Table 8 Status Quo Scenario

			Russia	Ukraine	Belarus	Western Europe
		Added Value	Allocation	Allocation	Allocation	Allocation
	RU	7959	995	995		
	RB	3664	458		458	
	Uwe					
	Bwe					
RU	RB	3664	153		153	
	UWe	10742		448		448
	Bwe					
RB	RU	7959	332	332		
	UWe					
	Bwe	4624			193	193
Uwe	RU	18701	779	779		
	RB	3664	153		153	
	Bwe					
Bwe	RU	7959	332	332		
	RB	8288	345		345	
	UWe					
RU,RB	UWe	10742		448		448
	Bwe	4624			193	193
RU,Uwe	RB	3664	153		153	
	Bwe					
RB,Bwe	RU	7959	332	332		
	UWe					
Uwe,Bwe	RU	18701	779	779		
	RB	8288	345		345	
RB,Uwe	RU	18701	779	779		
	Bwe	4624			193	193
RU,Bwe	RB	8288	345		345	
	UWe	10742		448		448
RU,RB,Uwe	Bwe	4624			578	578
RU,RB,Bwe	UWe	10742		1343		1343
RU,Uwe,Bwe	RB	8288	1036		1036	
RB,Uwe,Bwe	RU	18701	2338	2338		

Table 9 South Upgrade Scenario (Ukraine Buys)

			Russia	Ukraine	Belarus	Western Europe
		Added Value	Allocation	Allocation	Allocation	Allocation
	RU	10923	1365	1365		
	RB	3664	458		458	
	Uwe					
	Bwe					
RU	RB	3664	153		153	
	UWe	10742		448		448
	Bwe					
RB	RU	10923	455	455		
	UWe					
	Bwe	4624			193	193
Uwe	RU	21665	903	903		
	RB	3664	153		153	
	Bwe					
Bwe	RU	10923	455	455		
	RB	8288	345		345	
	UWe					
RU,RB	UWe	7778		324		324
	Bwe	4624			193	193
RU,Uwe	RB	700	29		29	
	Bwe					
RB,Bwe	RU	10923	455	455		
	UWe					
Uwe,Bwe	RU	21665	903	903		
	RB	8288	345		345	
RB,Uwe	RU	18701	779	779		
	Bwe	4624			193	193
RU,Bwe	RB	8288	345		345	
	UWe	10742		448		448
RU,RB,Uwe	Bwe	7587			948	948
RU,RB,Bwe	UWe	10742		1343		1343
RU,Uwe,Bwe	RB	8288	1036		1036	
RB,Uwe,Bwe	RU	21665	2708	2708		

Table 10 South Upgrade Scenario (Western Europe Buys)

			Russia	Ukraine	Belarus	Western Europe
		Added Value	Allocation	Allocation	Allocation	Allocation
	RU	7959	995	995		
	RB	3664	458		458	
	Uwe					
	Bwe					
RU	RB	3664	153		153	
	UWe	13145		548		548
	Bwe					
RB	RU	7959	332	332		
	UWe					
	Bwe	4624			193	193
Uwe	RU	21104	879	879		
	RB	3664	153		153	
	Bwe					
Bwe	RU	7959	332	332		
	RB	8288	345		345	
	UWe					
RU,RB	UWe	13145		548		548
	Bwe	4624			193	193
RU,Uwe	RB	3664	153		153	
	Bwe					
RB,Bwe	RU	7959	332	332		
	UWe					
Uwe,Bwe	RU	21104	879	879		
	RB	8288	345		345	
RB,Uwe	RU	21104	879	879		
	Bwe	4624			193	193
RU,Bwe	RB	8288	345		345	
	UWe	13145		548		548
RU,RB,Uwe	Bwe	4624			578	578
RU,RB,Bwe	UWe	13145		1643		1643
RU,Uwe,Bwe	RB	8288	1036		1036	
RB,Uwe,Bwe	RU	21104	2638	2638		

Table 11 Yamal Upgrade (Belarus Buys)

			Russia	Ukraine	Belarus	Western Europe
		Added Value	Allocation	Allocation	Allocation	Allocation
	RU	7959	995	995		
	RB	3664	458		458	
	Uwe					
	Bwe					
RU	RB	3664	153		153	
	UWe	10742		448		448
	Bwe					
RB	RU	7959	332	332		
	UWe					
	Bwe	16535			689	689
Uwe	RU	18701	779	779		
	RB	3664	153		153	
	Bwe					
Bwe	RU	7959	332	332		
	RB	20199	842		842	
	UWe					
RU,RB	UWe	10742		448		448
	Bwe	16535			689	689
RU,Uwe	RB	3664	153		153	
	Bwe					
RB,Bwe	RU	7959	332	332		
	UWe					
Uwe,Bwe	RU	18701	779	779		
	RB	20199	842		842	
RB,Uwe	RU	18701	779	779		
	Bwe	16535			689	689
RU,Bwe	RB	20199	842		842	
	UWe	10742		448		448
RU,RB,Uwe	Bwe	16535			2067	2067
RU,RB,Bwe	UWe	10742		1343		1343
RU,Uwe,Bwe	RB	20199	2525		2525	
RB,Uwe,Bwe	RU	18701	2338	2338		

Table 12 Nord Stream Scenario (Continued to Next Page)

			Russia	Ukraine	Belarus	Western Europe
		Added Value	Allocation	Allocation	Allocation	Allocation
	RU	1592	7959	796	796	
	RB	733	3664	366		366
	Uwe					
	Bwe					
	RWe	1632	8159	816		
RU	RB	183	3664	92		92
	UWe	537	10742		269	
	Bwe					
	RWe	408	8159	204		
RB	RU	398	7959	199	199	
	UWe					
	Bwe	231	4624			116
	RWe	408	8159	204		
Uwe	RU	935	18701	468	468	
	RB	183	3664	92		92
	Bwe					
	Rwe	408	8159	204		
Bwe	RU	398	7959	199	199	
	RB	414	8288	207		207
	UWe					
	RWe	408	8159	204		
Rwe	RU	398	7959	199	199	
	RB	183	3664	92		92
	UWe					
	Bwe					
RU,RB	UWe	358	10742		179	
	Bwe	154	4624			77
	RWe	272	8159	136		
RU,Uwe	RB	122	3664	61		61
	Bwe					
	RWe	272	8159	136		
RU,Bwe	RB	276	8288	138		138
	Uwe	358	10742		179	
	Rwe	272	8159	136		
RU,Rwe	RB	122	3664	61		61
	Bwe					
	UWe	358	10742		179	
RB,Uwe	RU	623	18701	312	312	
	Bwe	154	4624			77

			Russia	Ukraine	Belarus	Western Europe
	Rwe	272	8159	136		
RB,Bwe	RU	265	7959	133	133	
	UWe					
	RWe	272	8159	136		
RB,Rwe	RU	265	7959	133	133	
	UWe					
	Bwe	154	4624			77
Uwe,Bwe	RU	623	18701	312	312	
	RB	276	8288	138		138
	RWe	272	8159	136		
Uwe,Rwe	RU	623	18701	312	312	
	RB	122	3664	61		61
	Bwe					
Bwe,Rwe	RU	265	7959	133	133	
	RB	276	8288	138		138
	UWe					
RU,RB,Uwe	Bwe	231	4624			116
	RWe	408	8159	204		
RU,RB,Bwe	UWe	537	10742		269	
	RWe	408	8159	204		
RU,RB,Rwe	Uwe	537	10742		269	
	Bwe	231	4624			116
RU,Uwe,Bwe	RB	414	8288	207		207
	RWe	408	8159	204		
RU,Uwe,Rwe	RB	183	3664	92		92
	Bwe					
RU,Bwe,Rwe	Uwe	537	10742		269	
	RB	414	8288	207		207
RB,Uwe,Bwe	RU	935	18701	468	468	
	Rwe	408	8159	204		
RB,Uwe,Rwe	RU	935	18701	468	468	
	Bwe	231	4624			116
RB,Bwe,Rwe	RU	398	7959	199	199	
	Uwe					
Uwe,Bwe,Rwe	RU	935	18701	468	468	
	RB	414	8288	207		207
RU,RB,Uwe,Bwe	Rwe	1632	8159	816		
RU,RB,Uwe,Rwe	Bwe	925	4624			462
RU,RB,Bwe,Rwe	Uwe	2148	10742		1074	
RU,Uwe,Bwe,Rwe	RB	1658	8288	829		829
RB,Uwe,Bwe,Rwe	RU	3740	18701	1870	1870	

Appendix 2: Sensitivity Analysis for Natural Gas Price

Table 13 Sensitivity Analysis for Natural Gas Prices (Continued to Next Page)

RUSSIA	150	200	250	300	350	400	450
H&I - Status Quo	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%
H&I - South Upgrade	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%
H&I - Yamal	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%
H&I - Nord Stream	76.0%	76.1%	76.2%	76.3%	76.3%	76.3%	76.3%
N&H - Status Quo	37.1%	35.8%	35.2%	34.9%	34.7%	34.5%	34.4%
N&H - South Upgrade (U Buy)	37.7%	36.4%	35.8%	35.4%	35.2%	35.1%	35.0%
N&H - South Upgrade (We Buy)	36.8%	34.9%	34.1%	33.7%	33.5%	33.3%	33.2%
N&H - Yamal (B Buy)	37.1%	35.8%	35.2%	34.9%	34.7%	34.5%	34.4%
N&H - Yamal (We Buy)	32.8%	32.5%	32.3%	32.2%	32.2%	32.1%	32.1%
N&H - Nord Stream	40.0%	39.1%	38.7%	38.5%	38.4%	38.3%	38.2%
UKRAINE	150	200	250	300	350	400	450
H&I - Status Quo	34.6%	35.3%	35.5%	35.5%	35.6%	35.6%	35.6%
H&I - South Upgrade	34.6%	37.2%	37.3%	37.4%	37.5%	37.5%	37.5%
H&I - Yamal	23.1%	21.7%	21.5%	21.7%	21.8%	21.9%	21.9%
H&I - Nord Stream	18.3%	18.3%	18.2%	18.2%	18.2%	18.2%	18.2%
N&H - Status Quo	31.8%	34.6%	35.8%	36.5%	36.9%	37.2%	37.4%
N&H - South Upgrade (U Buy)	33.0%	35.3%	36.4%	36.9%	37.3%	37.6%	37.7%
N&H - South Upgrade (We Buy)	32.2%	35.9%	37.3%	38.1%	38.5%	38.8%	39.1%
N&H - Yamal (B Buy)	31.8%	34.6%	35.8%	36.5%	36.9%	37.2%	37.4%
N&H - Yamal (We Buy)	20.4%	24.0%	25.7%	26.7%	27.4%	27.9%	28.2%
N&H - Nord Stream	24.7%	26.6%	27.4%	27.8%	28.1%	28.3%	28.4%
BELARUS	150	200	250	300	350	400	450
H&I - Status Quo	15.4%	14.7%	14.5%	14.5%	14.4%	14.4%	14.4%
H&I - South Upgrade	15.4%	12.8%	12.7%	12.6%	12.5%	12.5%	12.5%
H&I - Yamal	26.9%	28.3%	28.5%	28.3%	28.2%	28.1%	28.1%
H&I - Nord Stream	5.6%	5.6%	5.6%	5.5%	5.5%	5.5%	5.5%
N&H - Status Quo	18.2%	15.4%	14.2%	13.5%	13.1%	12.8%	12.6%
N&H - South Upgrade (U Buy)	17.0%	14.7%	13.6%	13.1%	12.7%	12.4%	12.3%
N&H - South Upgrade (We Buy)	17.8%	14.1%	12.7%	11.9%	11.5%	11.2%	10.9%
N&H - Yamal (B Buy)	18.2%	15.4%	14.2%	13.5%	13.1%	12.8%	12.6%
N&H - Yamal (We Buy)	29.6%	26.0%	24.3%	23.3%	22.6%	22.1%	21.8%
N&H - Nord Stream	14.2%	11.8%	10.8%	10.3%	9.9%	9.7%	9.5%

WESTERN EUROPE	150	200	250	300	350	400	450
H&I - Status Quo	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
H&I - South Upgrade	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
H&I - Yamal	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
H&I - Nord Stream	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
N&H - Status Quo	12.9%	14.2%	14.8%	15.1%	15.3%	15.5%	15.6%
N&H - South Upgrade (U Buy)	12.3%	13.6%	14.2%	14.6%	14.8%	14.9%	15.0%
N&H - South Upgrade (We Buy)	13.2%	15.1%	15.9%	16.3%	16.5%	16.7%	16.8%
N&H - Yamal (B Buy)	12.9%	14.2%	14.8%	15.1%	15.3%	15.5%	15.6%
N&H - Yamal (We Buy)	17.2%	17.5%	17.7%	17.8%	17.8%	17.9%	17.9%
N&H - Nord Stream	21.1%	22.5%	23.1%	23.4%	23.6%	23.8%	23.9%

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my parents, my beloved wife Hiroko, my sister and all members of my family

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