

# **Strategic Investment in the Supply Chain for Russian Gas**

*A Shapley Value Analysis*

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## Abstract

In this thesis I use cooperative game theory – the Shapley value – to analyze the power structure in the supply chain for Russian gas and, furthermore, to evaluate the strategic impact of different investment options for creating new capacities. My results show that the possibilities to increase capacities along the existing tracks in Ukraine and Belarus, in order to bypass one of the transit countries, do not change the balance of power dramatically, whereas a direct, though very costly, link through the Baltic Sea, the *Nord Stream* pipeline, significantly strengthens Russia's strategic position. I also look into various factors on demand and supply side and investigate whether the construction of the *Nord Stream* pipeline may be superfluous.

## Foreword

This thesis is written as the final part of the Master of Science in Economics and Business Administration at the Norwegian School of Economics and Business Administration.

Being of Russian nationality, I have always been interested in my home country and paid attention to its relations with the outside world. The Russian natural gas industry seemed as a particularly interesting field of study not only due to the increasing European dependence on Russian gas, but also because of the gas conflicts between Russia and its transit countries over the past years; an issue that has received a great deal of attention in the media. My supervisor, Lars Mathiesen, has helped me to specify the topic of the thesis and to choose an appropriate theory for the analysis. I would like to thank him for all the help and support he has given during the process. I am also grateful to Svetlana Ikonnikova for her help with calculations of transportation costs of Russian gas, an area that I initially was not familiar with.

Bergen, December 2010

Marina Logacheva

# Contents

<b>ABSTRACT.....</b>	<b>2</b>
<b>FOREWORD.....</b>	<b>3</b>
<b>CONTENTS.....</b>	<b>4</b>
<b>1. INTRODUCTION .....</b>	<b>6</b>
<b>2. THE SUPPLY CHAIN FOR RUSSIAN GAS .....</b>	<b>10</b>
2.1 HISTORICAL BACKGROUND.....	10
2.2 SOUTHERN SYSTEM.....	12
2.3 YAMAL.....	13
2.4 NORD STREAM .....	15
2.5 SUMMARY .....	17
<b>3. MODEL .....</b>	<b>19</b>
3.1 THEORY.....	19
3.2 CALIBRATION .....	23
3.2.1 <i>Players and Pipelines</i> .....	24
3.2.2 <i>Capacity Cost</i> .....	25
3.2.3 <i>Demand and Production Cost</i> .....	26
<b>4. CALCULATIONS – A SIMPLE EXAMPLE .....</b>	<b>29</b>
<b>5. RESULTS.....</b>	<b>32</b>
5.1 THE POWER STRUCTURE IN THE SUPPLY CHAIN FOR RUSSIAN GAS .....	32
5.2 SUMMARY OF THE RESULTS .....	35
<b>6. CAN NORD STREAM BE SUPERFLUOUS? .....</b>	<b>38</b>
6.1 EUROPEAN GAS DEMAND .....	38
6.1.1 <i>European natural gas market</i> .....	38
6.1.2 <i>Climate Protection - The Policies of the European Union</i> .....	39

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6.1.3	<i>Renewable Energy Sources</i> .....	41
6.1.4	<i>Summary of the Demand Side</i> .....	41
6.2	SUPPLY OF RUSSIAN GAS .....	42
6.2.1	<i>The Production Capacity of Gazprom</i> .....	42
6.2.2	<i>Independent Producers</i> .....	43
6.2.3	<i>Investment and the Domestic Price Reform</i> .....	44
6.2.4	<i>The Role of Long-Term Contracts for the Allocation of Gazprom Supplies</i> .....	45
6.2.5	<i>Summary of the Supply Side</i> .....	46
7.	CONCLUSIONS.....	48
	REFERENCES .....	50
	APPENDIX A: TRANSPORTATION COST .....	53
	APPENDIX B: THE STRATEGIC VALUE OF PIPELINE OPTIONS .....	56

## 1. Introduction

The European dependence on Russian natural gas has been and continues to be a critical issue. For some decades, gas imports have been an important feature of Europe's gas supply, with the Russian Federation providing a quarter of EU consumption and more than 40% of its imports, which makes Russia the EU's single most important supplier of natural gas. The share of Russian hydrocarbons on the EU market is projected to remain high in the future, as the development within the EU over the past 20 years shows a clear trend towards increasing import dependency. Whereas both demand and production grew until the mid-1990s, production has since stabilised, and from 2004 it has been declining, while consumption level has kept rising. Considering not only the increased energy demand in Europe, but also the large Russian reserves of hydrocarbons, the geographical proximity of Russia and the EU, environmental concerns regarding other fuels (mainly coal) and the phasing-out of nuclear power in the EU, Russia is expected to be the swing supplier of natural gas to Europe for the foreseeable future.

Gazprom, Russia's dominant gas company, plans to boost export levels of gas to Europe in the years to come, increasing the supply from its current level of almost 100 bcm/a by another 50 bcm/a over the next decade. Such a growth of supply, however, requires heavy investment in transportation infrastructure linking customers in Western Europe to the main pipelines in Western Russia.

A high market share of Russian gas should not be any threat to Europe as long as deliveries are stable and predictable. To begin with, Russia's gas exports to Europe arrived via pipelines through Ukraine and Czech and Slovak Republics, and later on - Belarus and Poland. With the disintegration of the Soviet Union, Russia emerged as a central player owning most of the gas fields and essential pipelines. However, it also became dependent on newly independent transit countries as they have inherited the pipelines crossing their soil. While some countries, such as Slovakia and Czech Republic, managed to find a stable long-term solution for their gas relations with Russia, others, such as Ukraine and Belarus, engaged in continuous bargaining over prices and transit fees, leveraging their strategic positions in the export chain. Disagreements on the terms of sale and transit of Russian gas through the transit countries have resulted in several gas supply interruptions, affecting EU Member States to varying degrees. The supply interruptions have caused broad concerns in

Europe regarding energy security and undermined Russia's role as a reliable supplier of natural gas.

In this thesis I look at three options for Russia to increase its transmission capacity in order to meet the additional import needs of Europe. The cheapest option is to upgrade the old system in Ukraine which was built in Soviet times. As the second cheapest option for creating new capacities comes a new pipeline passing through Belarus, which would be built along the already existing pipeline, known as *Yamal 1*. However, the turmoil surrounding Russia's relations with the transit countries led Gazprom to start looking for a direct link to its customers in Western Europe. As a diversification alternative for Gazprom's export routes, Russia is planning to build a direct offshore pipeline between Germany and Russia, known as *Nord Stream*. *Nord Stream* is by far the most expensive option for creating new capacities. However, it would have the advantage, for the Russian supplier, of not crossing any of the traditional transit countries such as Ukraine and Belarus.

In order to disentangle the commercial reasons to increase the transmission capacity from the strategic aspects of investment and, further, to analyze the power structure in the supply chain for Russian gas, I use cooperative game theory - the Shapley value. I model the interdependencies in the gas network as a game in value function form. The solution of the game allocates to each country a share in the total profit. The relative size of payoff indicates the strength of the player's position and can be interpreted as his bargaining power, or power index. By applying the Shapley value, I derive the bargaining power of the different players along this supply chain endogenously from the architecture of the pipeline network and the various options to modify it. Here lies the advantage of the Shapley value approach, as it does not require any specific assumptions about details of the bargaining process, sequences of moves etc.

The disruptions of Russian gas supplies to Western Europe, caused by recurrent conflicts between Russia and its transit countries, shed light on the powerful position of the transit countries in the supply chain. From a short-term perspective, the power of a player appears to be determined by his control of existing transport capacities. The status quo, however, can be changed by adding new pipelines to the existing system. Consequently, the analysis of the power structure in the network depends on what is considered to be the relevant scope of the game. I consider two borderline cases of extreme 'shortsightedness' and 'farsightedness' which define the scope of the game. The short-sighted scenario is represented by the "status

quo” game, for which the game’s value function is derived by allowing for the use of existing capacities only. The “all options” game represents the far-sighted scenario. Here the value of a coalition is derived by allowing for optimal investment in all pipelines, which do not cross the territory of outside players.

Solving the model numerically, I find that the scope of the game is of outmost importance for the assessment of the power structure. In the short-sighted “status quo” game, Belarus and Ukraine appear to be much stronger than in the far-sighted “all options” game, in which Russia’s bargaining position is strengthened significantly. Looking at the impact of each single pipeline option on the power index, I find that the possibilities to increase capacities along the existing tracks in Ukraine or Belarus do not change the balance of power dramatically. By far the strongest impact on the bargaining power is exerted by *Nord Stream*. Although this project cannot compete commercially with the other options to increase transport capacity, it strengthens Russia’s bargaining position more than all other options together. In other words, in the supply chain for Russian gas, competition between Belarus and Ukraine is of little strategic importance compared to Russia’s direct access to its customers in Western Europe.

The thesis also investigates a viewpoint that it does not necessarily need to be the turmoil between Russia and its transit countries that is the largest threat to both large and stable Russian gas supplies to Europe. There are several other challenges and uncertainties within the Russian natural gas industry that have to be dealt with when the predictions of future Russian gas exports are made. Russia currently struggles with undefined depletion rates for several giant operating gas fields due to uncertain and unique physical characteristics. Furthermore, there is a lack of financial ability to compensate for the observed production decline and to upgrade the aging transportation network. Finally, there are major uncertainties associated with the speed and effect of the domestic Russian gas market reforms. There have recently been studies revealing that if Russian gas prices approach the international market levels, Europe may no longer be the preferred selling market for Russian gas producers, see e.g. Sagen & Tsygankova (2007)

On the demand side, the future development of the European gas demand relies heavily on growing awareness of environmental concerns and related regulations in the European Union. These and other factors, that have potential to affect the supply of Russian natural gas and the future gas demand in Europe, are discussed in the thesis.



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This thesis is to a large degree inspired by “Investment Options and Bargaining Power in the Eurasian Supply Chain for Natural Gas” – a study by Franz Hubert and Svetlana Ikonnikova (2009). They model the pipeline construction in the Eurasian gas market as a bargaining process between one producer, Russia, and several potential transit countries: Ukraine, Belarus, Poland, Slovakia, Latvia and Lithuania. In order to derive the power structure in the supply chain, Hubert & Ikonnikova (2009) apply three cooperative game concepts: the Shapley value, the core and the nucleolus.

In contrast to Hubert & Ikonnikova (2009), I confine myself to the Shapley value and look more deeply into this solution concept for multilateral bargaining. As to the players involved in the game, I consider Russia, which is the single producer of natural gas, and two transit countries: Ukraine and Belarus. I restrict myself to these two transit countries because of their difficult gas relations with Russia which have by several occasions resulted in supply interruptions of Russian gas to Western Europe. The main aim of my thesis is to analyze the balance of power in the gas network and how it could be altered through various investment options for creating new capacities.

The issue of Russian gas transit to Europe has been covered to some extent in the modern literature. To name a few examples, Varro (2006) analyzes the thorny gas relations between Russia and Ukraine as an unstable “Chicken game” resulting from the bilateral monopoly situation between the two countries. Hirschhausen et al. (2005) study the options of transporting Russian gas to Western Europe, with a focus on the relations between Russia and Ukraine, where they model non-cooperative and cooperative strategies for two- and three player games.

The rest of the thesis is organized as follows. The next section provides the historical background and describes the main features of the Eurasian supply system for natural gas. In section 3 I introduce the Shapley value concept and calibrate the model. Section 4 provides a simple example demonstrating how the Shapley value is calculated. I present and interpret the numerical results in section 5. Section 6 investigates future development of gas demand in Europe as well as it looks into potential challenges within the Russian natural gas industry. Section 7 concludes.

## 2. The Supply Chain for Russian Gas

### 2.1 Historical Background

Russian transmission system for natural gas, originally shaped during the 70s and 80s, is formed as a network of pipelines stretching from gas fields in Siberia and Central Asia to Western Russia and further on to the industrial centres in Western Europe. The backbone of the network, Brotherhood-Transgas (labelled “Transgas” in Figure 1), was already built in Soviet times. This transcontinental pipeline, passing through Ukraine, Slovakia and Czech Republic, is the main corridor for Russia’s gas exports, as approximately 80% of exports are taking this route prior to arriving in the EU.

**FIGURE 1: Existing and Planned Natural Gas Pipelines to Europe**



Source: U.S. Energy Information Administration

In Soviet times, when Ukraine was a part of the USSR and former Czechoslovakia belonged to the CMEA block, there were no transit problems. Russia’s relations with the former Soviet Union countries were characterized by a high degree of economic and political interdependence, and this was particularly evident in the energy industry. The transit countries enjoyed only limited freedom to pursue their own agenda and the Soviet Union,

concerned with being regarded as a reliable gas supplier, strictly complied with all its obligations. When the USSR disintegrated, Russia was faced with the question of how to relate to the fourteen newly emerged sovereign states. This issue set off a wider debate in Russia on whether the country should pursue integration with Europe, or whether its geographical position afforded it a special role between East and West.

Russia inherited most of the Soviet's gas fields and essential transport pipelines and, consequently, controls critical bottleneck facilities and dominates supplies to energy-importing countries. At present, even Central Asian exporter countries depend on transport through Russian pipelines to reach customers.

However, with the disintegration of the Soviet Union, Russia also became dependent on three newly independent transit countries, Slovakia, Czech Republic and Ukraine, for the final delivery of natural gas to the markets in Western Europe. These countries have inherited the pipeline infrastructure developed on their territory and became Russia's only supply route to Western Europe. In a way, these gas pipelines crossing the region symbolize the intense economic interdependence of the former Soviet states.

By 1993, the Russian government adopted a foreign policy orientation where it sought to pursue a "Russia first" policy in its relations with the West at the same time as it aimed to re-exert Russia's sphere of influence in the former Soviet Union, acknowledging the importance of relations with the other Commonwealth of Independent States (CIS) countries. The CIS has been as much a means of the separation of member countries from the hegemony of Russia as for their integration. While some countries aimed for closer relations with Russia, others sought to maintain their newfound sovereignty.

Slovakia and Czech Republic privatized their sections of the southern system and sold them to western importers. Emerging from former Czechoslovakia, these countries benefited from old contracts with the Soviet Union, which entitled them to large deliveries of gas at low cost. Both countries developed stable commercial gas relations with Russia and transit never became an issue. Ukraine and Russia, in contrast, failed to find a stable long-term solution for their gas relationship.

## 2.2 Southern System

Following the collapse of the Soviet Union, oil import prices to Ukraine soon reached world market levels, however gas import prices and transit fees for Russia's exports through pipelines in Ukraine were set in bilateral negotiations. Russia's dependence on gas transit through Ukraine to reach western markets provided Ukraine with significant bargaining power in the price negotiations with Gazprom. Hence, prices for Russian gas in Ukraine were considerably lower than prices paid in Europe, though they were still somewhat higher than prices inside Russia.

Russia tried to privatize Ukrainian pipelines, but was not successful due to strong Ukrainian commitment to seek rents. Ukraine consolidated its pipeline system in a state owned national monopoly, Naftogas, which is in charge of domestic supply and international transit. Throughout the nineties Gazprom and Naftogas were constantly involved in recurrent disputes over fees for transit service, the price for Ukraine's additional gas imports, delinquent debts etc. The unauthorized use of Russian gas by Ukraine has added to the problem.

Given that Ukraine's gas import and transit arrangements are closely intertwined, the situation on the Ukrainian domestic gas market and the country's trade relations with Russia have the potential to have serious implications for consumers in Western Europe. Disagreements on the terms of sale and transit of Russian gas through Ukraine have led to gas supply interruptions in January 2006, March 2008 and January 2009. While the interruption in 2008 was entirely absorbed by Ukraine, the interruptions in 2006 and 2009 affected EU Member States to varying degrees, with the interruption in 2009 becoming the most serious to date.

In the early days of January 2009 a commercial dispute between Gazprom and Naftogas provoked a 3-week interruption of natural gas supply on the EU – Ukrainian border. The gas crisis began with a failure to reach an agreement on gas prices and supplies for 2009. On 1 January 2009, Gazprom reduced the gas supply to Ukraine, while keeping transit to the European Union at steady level. In response, Ukraine started to take gas illegally from the transit pipelines. In the following days the situation deteriorated with several European countries reporting major falls or cut-offs of their gas supplies from Russia transported through Ukraine. On January 7, the transit of natural gas to Ukraine was completely shut off

by Russia. Meanwhile, the gas contract with Russia was still not signed because Ukraine declined Russia's offer for gas import and transit prices. The conflict was resolved on January 19, when the head of Gazprom, Alexei Miller, and the head of Naftogaz, Oleh Dubyna, signed an agreement on natural gas supplies to Ukraine for the period of 2009-2019.

Unsurprisingly, the largest falls in gas consumption during January 2009 were recorded in the Member States which were the worst affected by the gas dispute. During that time, Bulgaria, Romania and Greece experienced reductions in natural gas imports of 54%, 86% and 23% respectively: roughly equivalent to the volumes of missing gas deliveries coming from the Russian Federation via Ukraine. Whereas earlier interruptions of gas supplies to Western Europe have been extremely rare and short lived, leaving no lasting impact on customers in the West, the crisis of 2009 caused irreparable and irreversible damage to customers' confidence in Russia and Ukraine. It has highlighted Russia's vulnerability and shed light on the powerful position of Ukraine in the supply chain for Russian gas.

## 2.3 Yamal

Eager to diversify its export channels and weaken Ukraine's powerful position in the export chain, Russia turned to Belarus and Poland. After gaining independence Belarus remained closely allied with Moscow and formed a loose union state with Russia. Belarus has close historical and cultural ties to Russia as well as being its second largest trading partner. To Belarus, Russia represents an important political ally, and it has also been Belarus' primary source of cheap fuel. Since 1992, Russia has supplied Belarus with subsidized gas, with prices for Belarus being typically lower than anywhere in the CIS region. Belarus depends on Russia for its annual gas demand of 18 bcm and has been chronically indebted to Gazprom throughout the post-Soviet period.

When the USSR disintegrated, Russia and Belarus agreed on a long-term solution for sales of natural gas and transit relationships. In September 1993, Russia made its first move to gain control of Belarus's gas transmission network with the signing of an agreement on the transfer of BelTransGaz, Belarus's national transmission company, to Gazprom. Under the terms of the agreement, Belarus agreed on a 99-year lease of land for new pipelines which would be owned by Gazprom and operated by BelTransGaz. Belarus also agreed to ensure the uninhibited transit of Russian gas across its territory for export. In controlling

BelTransGaz, the Russian government would achieve greater security of Gazprom's exports across Belarus to Europe, and at the same time remove an important lever of manipulation – transit capacity. For the section in Poland a joint stock company, EuroPolGaz, was established in which Polish PGNiG and Russian Gazprom both equally hold 48%. The remaining stake of 4% is held by a small company, Gas-Trading, which tips the balance in favour of the Polish side.

This encouraged Gazprom to revive old, ambitious plans to develop the huge Yamal field and connect it to internal and external markets with a new massive northern route. Eventually, attention focused on the export pipeline through Belarus, which would deliver natural gas from Russia to Poland and Germany. The first leg of the pipeline, now commonly referred to as *Yamal 1*, went into operation in 1999. It has been conceived primarily as a means of avoiding transit through Ukraine, and as a more reliable route. In 2006 three compressor stations were installed on the Belarus section of the Yamal pipeline, aimed at bringing it up to the target capacity of 28 bcm/a.

Although Belarus offers the quickest and cheapest path to Europe, it is uncertain whether the second string of the Yamal line will be built. The construction of the second pipeline, *Yamal 2*, with a potential of another 28 bcm/a has already been started, however its completion seems to be very unlikely by now, partly as a result of a more tense gas relationship between Russia and Belarus, and Gazprom's strategy of reducing its transit vulnerability.

The relationship between Russia and Belarus has cooled down considerably with the advent of Vladimir Putin as the president of the Russian Federation in 2000. Although Putin advocated CIS integration, he also indicated that more strict commercial conditions would apply. Putin stressed the need to receive gas payments, even from those countries politically close to Russia.

Gas relations between Gazprom and Belarus deteriorated for two reasons. First, Belarus was reluctant to pay higher gas prices. Like Ukraine, Belarus used its new strategic position in the export chain to gain concessions for its own gas imports. Second, Belarus was unwilling to move forward with the privatization of BelTransGaz, creating tensions at the political and commercial levels. In April 2002, Belarus and Russia signed an agreement whereby Gazprom would supply the republic with gas at Russia's domestic price; furthermore it would cancel Belarus' accumulated debt on condition that Gazprom would receive up to a

50% share in BelTransGaz. However, the second part of the agreement, which would have given Gazprom much more effective control over its export routes, was never fulfilled.

Minsk and Moscow were not able to reach a compromise, and on 1 January 2004 Gazprom suspended gas deliveries to Belarus. Belarus responded to the cut-off by siphoning gas destined for Europe via the Yamal pipeline. The dispute reached its climax on 18 February when Gazprom imposed a total cut-off, deliberately shutting down supplies not only to Belarus but also to Western Europe. The total cut-off lasted less than a day and did not affect Gazprom's customers in the West; nevertheless it raised serious supply concerns in Europe, and highlighted the fact that Gazprom has not solved the transit issue.

## 2.4 Nord Stream

The turmoil surrounding Russia's relations with transit countries led Gazprom to start searching for a direct way of delivering natural gas to its customers in Western Europe. Plans for a direct offshore connection between Russia and Germany have been discussed since the late nineties; however, the implementation of the project was constantly postponed as it seemed to be commercially unviable. Nevertheless, in September 2005, an agreement was signed on the construction of a twin pipeline, later named *Nord Stream*, which would link Russia with Germany via the Baltic Sea. The aim of the pipeline is to transport Russian gas into Western Europe while bypassing transit countries such as Ukraine and Belarus.

The *Nord Stream* offshore pipeline will be operated by Nord Stream AG, a joint company where Gazprom is the majority shareholder with 51% of shares. In addition to Gazprom, Nord Stream comprises two German companies E.ON Ruhrgas and BASF/Wintershall, each with 20%, and Gasunie of the Netherlands holding the remaining 9%.

*Nord Stream*, also known as North Transgas and the North European Gas Pipeline (NEGP), is a planned 1200km long offshore pipeline from Vyborg in Russia to Greifswald in Germany through the Baltic Sea. When constructed, *Nord Stream* will be among the longest offshore pipelines of the world. It will have two parallel legs, each with an annual capacity of 27.5 bcm of natural gas, bringing an additional 55 bcm per year of supply capacity to the European market. The gas will originate in the already developed Yuzhno Russkoye field and, later on, in the Yamal Peninsula, Ob-Taz Bay and the Shtokman fields. The first gas delivery is scheduled for late 2011.

The interpretations of the Nord Stream project are very different in the various states. While some countries, most notably Germany and Russia, are eager proponents of the project, others seem to be more sceptical to the projects implementation.

The party that would benefit the most from the construction of *Nord Stream* appears to be the European Union. As mentioned in the introduction, the development within the EU over the past 20 years shows a clear trend towards increasing import dependency. The EU as a whole faces a growing need for external energy supplies. In this context, *Nord Stream* can play an important role, as it will meet a quarter of the additional import needs of Europe.

*Nord Stream* would also be an important step on the way to increased diversification of supply routes. As discussed previously, the European Union has experienced several gas supply interruptions resulting from the challenging gas relationship between Russia and its transit countries. This new direct energy link between the EU and Russia would make it possible to circumvent the transit countries and, hence, increase the security of supplies.

The European Commission has expressed its support for the Nord Stream project and has given the pipeline status as a priority project under the TEN-E guidelines (Trans-European Energy Network). The TEN-E guidelines are meant to help increase competitiveness in the energy market and increase security of supply. By giving priority to certain projects, the EU aims to “accelerate the implementation and construction of connections and to increase the incentives for private investors” (EU Commission 2006: 2). However, it should be noted that the label “project of European interest” under the TEN-E guidelines does not imply that all of Europe will benefit from it.

There are a significant number of states within the European Union that have harshly criticised the project since its birth, and some of them have even accused Germany of being guilty of putting its own interests above those of other member states. Even without taking into consideration the future gas needs of the EU, one cannot disregard the fact that *Nord Stream* will run ashore in Germany and the bulk of the gas would be earmarked for the German market. Hence, the project would serve this state more than any other within the union. Germany is Russia’s main partner among the old EU member states and Russia’s gas supplies account for some 40% of the country’s annual gas need.

Whereas *Nord Stream* may be an answer to Germany’s energy dilemma, the Baltic States have perceived the pipeline as a problem in itself, and this is to a large extent due to their



history with Russia. All the three Baltic States have experienced energy cut-offs or other strong reactions from Russia following political or commercial disputes. Hence, the Baltic States have interpreted the pipeline as a politically motivated strategy that will increase Russia's leverage on them and threaten their energy security. If *Nord Stream* is constructed, Russia could potentially cut supplies to East European states without it affecting the supply levels to Germany.

For the Russian supplier, *Nord Stream* would have the advantage of not crossing any of the traditional transit countries - Ukraine, Slovak and Czech Republics, and more recently Belarus. If *Nord Stream* is built and fully utilised, it is possible that historical transit routes, Brotherhood-Transgas and Yamal, will have lower capacity utilisation rates, making Russia less dependent on the transit countries.

## 2.5 Summary

To summarise, the post-Soviet developments in the transport network for Russian natural gas reflect to a large extent Russia's reactions to the strength of Ukraine's position in the inherited system. Ukraine has been dominating the export chain for Russian gas since it became Russia's only supply route to Western Europe after the dissolution of the Soviet Union. The completion of a new corridor through Belarus in 1999, the *Yamal 1* pipeline, has modified the situation, but not profoundly. Both Ukraine and Belarus have engaged in continuous bargaining with Russia over prices and transit fees, leveraging their strategic positions in the export chain to gain concessions for their own gas imports. The turmoil surrounding the relations between Russia and the transit countries has resulted in several gas conflicts affecting Russia's customers in the West and undermining their confidence in Russia as a reliable supplier.

In order to secure much-needed gas supplies to an increasingly energy-thirsty European Union and, at the same time, reduce the transit countries' position as a potential counter-lever, Russia has considered various projects such as *Yamal 2* and *Nord Stream*. While the costs of establishing alternative supply routes are well known, their strategic value is more difficult to estimate. In the next section I introduce a formal model of how network architecture and investment options determine the bargaining power of different players and the sharing of profits from gas exports. This framework can then be used to analyze whether building Yamal has helped Russia to strengthen its bargaining position and discipline

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Ukraine, and what is the effect of the even more costly option to diversify export routes – the *Nord Stream* pipeline.

### 3. Model

As mentioned in the introduction, I will analyze the power structure in the supply chain for Russian gas by applying cooperative game theory – the Shapley value. I model the interdependencies in the supply chain as a game in value function form, which is calibrated using information on the cost of different pipelines, assumptions on demand for gas and production costs etc. The solution of the game allocates to each country a share in the total profit. The relative size of payoff indicates the strength of the player's position and can be interpreted as his bargaining power, or power index. Any change in demand for gas, network architecture, transportation cost etc. will yield a new value function.

#### 3.1 Theory

Shapley value is a game theory concept proposed by Lloyd Shapley in 1953. The aim of the concept is to suggest a fair allocation of profits obtained by cooperation among several players, and further, to find the relative importance of each player regarding his contribution to the cooperation. When a group of players form a coalition in order to cooperate and gain profits, each player makes a contribution to the coalition. However, the size of the various contributions differs, as some players may contribute more to the coalition than the others. Consequently, the allocation of collectively gained profits between the players should be made according to the contribution of each player to the coalition. Intuitively, the power of a player should increase as he becomes more important to other players. The Shapley value concept enables to measure exactly the “importance”, or the power, of a particular player by looking at the contributions that the player can make to the various possible coalitions.

The interdependencies among the players are represented by a game in value function form  $(N, v)$ , where  $N$  denotes the set of players and  $v$  is the characteristic function, also called value function. The set  $N$  consists of  $n$  players which may form arbitrary coalitions  $K$  with  $k \leq n$  players. The value function  $v(K)$  is the minimum total payoff that coalition  $K$  can guarantee to its members.<sup>1</sup>

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<sup>1</sup> Dixit, Avinash K. and Susan Skeath (1999): *Games of Strategy*. Norton, pp. 572-577.

The Shapley Value is an allocation of payoffs  $\phi_i(v)$  to each player  $i$  as defined by:<sup>2</sup>

$$\phi_i(v) = \sum_{K \subset N} [v(K) - v(K \setminus \{i\})] \frac{(k-1)!(n-k)!}{n!}$$

$\phi_i(v)$  is the sum-product of two terms: i) The marginal contribution of player  $i$  to coalition  $K$  and ii) the probability of coalition  $K$  including player  $i$ . The rationale behind this is that each player should be given a payoff equal to the average of the contributions he makes to each coalition to which he could belong, where all coalitions of the same size are equally likely.

Consider that there is one original coalition  $K$  and that a player  $i$  joins it. The contribution of player  $i$  is evaluated by comparing the value of the coalition  $K$  including player  $i$ ,  $v(K)$ , minus the value that the coalition  $K$  can obtain without him,  $v(K \setminus \{i\})$ . The marginal contribution of player  $i$  is:

$$MC(i, K) = v(K) - v(K \setminus \{i\})$$

Next, consider the size of the coalition  $K$ . Size  $k$  of the coalition ranges from 1 to  $n$ . Since all sizes are equally likely, a particular size coalition occurs with probability  $\frac{1}{n}$ . Then the

$(k-1)$  partners of player  $i$  in a coalition of size  $k$  can be chosen from among the remaining  $(n-1)$  players in any of  $C(n, k) = \frac{(n-1)!}{(k-1)!(n-k)!}$  ways.<sup>3</sup> The reciprocal of this expression is

the probability of any such choice of partners:  $p(n, k) = \frac{(k-1)!(n-k)!}{(n-1)!}$ . Combining that

reciprocal with  $\frac{1}{n}$  yields the probability of a particular coalition  $K$  of size  $k$  with player  $i$  as a member:

<sup>2</sup> Friedman, James W. (1986): *Game Theory with Applications to Economics*. Oxford University Press, p.209.

<sup>3</sup> Lillestøl, Jostein (1997): *Sannsynlighetsregning og statistikk med anvendelser*. Cappelen Akademisk, issue 4, p.44. Simple random sample of  $s$  from a population  $N$ ;  $(N \setminus s) = \frac{N!}{s!(N-s)!}$ .

$$P(n, k) = \frac{(k-1)!(n-k)!}{(n-1)!n} = \frac{(k-1)!(n-k)!}{n!}$$

Hence, the Shapley value payoff to each player is a weighted average of the contributions that the player makes to each of the coalitions to which he belongs with the weights depending on the number of players,  $n$ , and the number of members in each coalition. (Friedman 1986)

However, in this thesis I want to compare different network layouts, i.e. games with different compositions of players. Therefore, it is more convenient to look at the relative size of payoff assigned to a player in a game in order to estimate the strength of the player's positions, or his power index. A player's power index is obtained by dividing the payoff allocated to the player by the sum of payoffs of all the players participating in the game. It should be noted that the payoffs  $\phi_i(v)$  of all the players sum to the characteristic function  $v$  of the grand coalition of all players.

The Shapley value can also be seen as a way of achieving a market-like outcome, at least approximately, when an actual market does not exist or cannot be arranged. A market mechanism would automatically reward each participant for his contribution. The Shapley value concept implies that a player must make an effort in order to generate his contribution. The fact that each player will be rewarded according to his contribution, gives the player the correct incentive to make that effort.

Another appealing feature of the Shapley value is the lack of requirements about assumptions on details of the bargaining process, sequences of moves etc. Instead it is based on four axioms which define the value uniquely.

- 1) Efficiency: Total gains available to the grand coalition are fully allocated between the players,  $\sum_{i \in N} \phi_i(v) = v(N)$ .
- 2) Symmetry: Players  $i, j \in N$  are said to be symmetric with respect to game  $v$  if they make the same marginal contribution to any coalition, i.e. for each  $K \subset N$  with  $i, j \notin K$ ,  $v(K \cup \{i\}) = v(K \cup \{j\})$ . The symmetry axiom requires symmetric players to be paid equal shares,  $\phi_i(v) = \phi_j(v)$ .

- 3) Dummy player: If a player  $i$  adds nothing more than  $v(\{i\})$  to any coalition, then the player receives only  $v(\{i\})$ . A dummy player, that is a player whose marginal contribution is null with respect to every coalition, is to be assigned zero payoffs. If  $i$  is a dummy player, i.e.,  $v(K) - v(K \setminus \{i\}) = 0$  for every  $K \subset N$ , then  $\phi_i(v) = 0$ .
- 4) Additivity: If a game is formed by adding two games together, where the game  $v + w$  is defined by  $(v + w)(K) = v(K) + w(K)$  for all  $K \subset N$ , then the Shapley value of the new game is the sum of the values of the two original games,  $\phi(v + w) = \phi(v) + \phi(w)$ .

The four conditions defined above yield a unique outcome; however, one must decide whether these properties are ultimately acceptable and, furthermore, equally desirable. Most importantly, each player would consider not the attractiveness of the properties, but the outcome that they would give him. If an outcome is not satisfactory for some players, or they believe they can do better by participating in a different game, the proposed solution of the game may not be accepted.

Another aspect of the Shapley value definition, which may not have any counterpart in reality, is the probability of each coalition. As mentioned above, all coalitions of the same size are regarded as equally likely. In the case of the supply chain for Russian gas, the probability of coalitions between Russia, Ukraine and Belarus may depend on the former gas relations between the countries, present relations at the political and commercial levels, historical and cultural ties etc.

Moreover, a coalition's payoff may depend on the actions of players external to the coalition. Fortunately, this problem does not occur in this case because one player, Russia, is essential in the game. Coalitions which do not include Russia cannot establish a complete supply chain in order to export Russian gas, neither can they compete with the coalitions which include Russia.<sup>4</sup>

As noted in the introduction, I will consider different value functions in order to reflect various assumptions about the scope of the game. The scope of the game is defined by two borderline cases of extreme 'shortsightedness' and 'farsightedness'. The short-sighted

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<sup>4</sup> Hubert, Franz and Svetlana Ikonnikova (September 2009): *Investment Options and Bargaining Power in the Eurasian Supply Chain for Natural Gas*. Humboldt.

scenario is represented by the “status quo” game, where the existing capacities can not be changed. Hence, the power of a player is determined by his control over the installed pipelines. The status quo, however, can be changed by adding new pipelines to the existing transmission system. Therefore, a rational farsighted player should take into account all relevant options to extend the network in order to obtain a comprehensive evaluation of his bargaining power. To assess the strategic impact of each investment option, I add that option to the status quo game and evaluate the changes it gives in the power structure. The “all options” game represents the far-sighted scenario. Here the value of a coalition is derived by allowing for optimal investment in all pipelines which do not cross the territory of the players external to the coalition. To focus on the strategic impact of the various investment options, I initially assume that the projects can be implemented immediately. I also assume a stationary environment with respect to technology, demand, etc, so that optimal investment is independent of the potential delay.

## 3.2 Calibration

In the following I calibrate the model to reflect the main features of the Eurasian gas network at the beginning of the new century. The profit that a particular coalition can achieve depends on demand for Russian gas and on production and transportation costs. The latter depends on the geographical position of the coalition’s members, past investment in transportation network and on the options to extend it. Details are given in the appendix. As the focus of this thesis is on the power structure within the Eurasian supply chain for natural gas, I do not take into consideration the strategic interaction between Russia and competing suppliers such as Norway and Algeria except for when I make assumptions on the residual demand for Russian gas. This will be discussed later in the thesis.

I also restrict myself with respect to the geographic scope of the analysis as I do not take into consideration gas supplies to Europe which are delivered through the pipelines located in Southeastern Europe and Central Asia. However, there are gas pipelines from the southern side, both proposed and existing, that could be rivals to the *Nord Stream* pipeline. The *South Stream* pipeline is a proposed gas pipeline that would deliver Russian gas through the Black sea to Bulgaria and further to Italy and Austria. *South Stream* is seen as a rival to the planed *Nabucco* pipeline, which would supply gas from Iran and Azerbaijan through Turkey to Austria and Hungary, reducing the region’s dependence on Russian gas. Moreover, there are

plans for a submarine pipeline between Turkmenistan and Azerbaijan, known as The Trans-Caspian Gas Pipeline. The Trans-Caspian Gas Pipeline, if built, would transport natural gas from Turkmenistan and Kazakhstan to Central Europe, circumventing both Russia and Iran. The possibility of competing supply routes may challenge the strategic position of *Nord Stream* and should therefore be taken into account when performing an economic analysis of the Nord Stream project. However, this is not the aim of this thesis, and therefore the possibility of competing pipelines through Southeastern Europe and Central Asia is outside the scope of my analysis.

### 3.2.1 Players and Pipelines

The main players in the supply chain are *Russia*, *Ukraine* and *Belarus*. Using the capital letters for the initials of the countries, the set of players is  $N = \{R, U, B\}$ . The pipelines considered in the model are the old system through Ukraine, which I will refer to as *South*, the possibility to upgrade and extend it, referred to as *Upgrade*, the *Yamal 1* pipeline passing through Belarus and its possible extension *Yamal 2*, and finally the direct link from Russia to Germany - the *Nord Stream* pipeline.

Even though a large section of the southern system is located in Slovakia and Czech Republic, I will not consider these countries as autonomous players. As already mentioned in section 2.1 “Historical background”, these countries have privatized their transit pipelines after the dissolution of the Soviet Union and sold them to Western gas importers, whose property rights are constitutionally protected. Being the members of the European Union, these countries have to adhere to EU agreements and thus cannot interfere with gas transit to gain leverage in international negotiations.

Poland is not considered as an autonomous player either, even though a section of *Yamal 1* is located in the country and the Polish side has a controlling stake in EuroPolGaz. As a member of the European Union, Poland cannot obstruct the use of *Yamal 1*. Long term agreements and constitutional rights as well as EU regulations effectively assure Russia’s access to the pipeline.



### 3.2.2 Capacity Cost

All pipeline options considered in the model establish a complete link between Russia and Western Europe. However, there are important differences in transportations costs. The estimated transportation costs for each of the pipelines can be found in the appendix. By far the cheapest options to serve the market are *Yamal 1*, with a capacity of 28 bcm/a, and the old transmission system through Ukraine, *South*, with a capacity of approximately 70 bcm/a. Investment cost for these pipelines is sunk. However, due to aging compressors, lack of maintenance and underinvestment, the capacity of *South* is in decline. Up to a limit of about 15 bcm/a, the cheapest option for creating new capacities is the renovation of the southern system, *Upgrade*. For capacity increases beyond that threshold, *Yamal 2* comes as the second cheapest option, with a capacity cost which is two times larger. Here investment would benefit from preparations made during construction of *Yamal 1*, which was constructed in such a way that it would be possible to add a second pipeline at a later stage. By far the most expensive option is *Nord Stream*, which requires at least another doubling of capital expenditure per unit of capacity.

Table 1: Capacity Cost

project	capacity (bcm/a)	investment (bn\$)	capacity cost (\$/tcm)
<b>South</b>	70	sunk	sunk
The old southern system in poor state of repair.			
<b>Upgrade</b>	15	0,75	50
Repaires and replacement of old compressor stations using the existing pipeline capacities.			
<b>Yamal 1</b>	28	sunk	sunk
Pipeline from Torzok to Germany, operating since 1999.			
<b>Yamal 2*</b>	28	2,4	99
New pipeline parallel to <i>Yamal 1</i> with some preparations already made.			
<b>Nord Stream*</b>	55	10,3	215
New pipeline from Greifswald (Germany) - Vyborg (Russia) 1200km offshore, then 400km onshore to Torzhok.			

\* As these are new projects, which take considerable time to complete, investment cost is increased by 15% to account for interest during construction.

### 3.2.3 Demand and Production Cost

Finally, I have to make assumptions on demand for Russian gas in Western Europe and the cost of producing and transporting it to the border of Western Europe. Unfortunately, the calibration with respect to demand and production cost cannot be based on solid data. Current gas production depends on past investment in gas fields and transport facilities, investment cost of which is sunk. However, Russia's giant gas fields, which have accounted for most of the country's output for decades, have all reached their decline phase of production. Russian gas production is transforming from one based on existing production to one increasingly dominated by production from new, more difficult-to-develop regions needing new transportation infrastructure. Hence, the production cost of Russian gas depends on production from old fields, the cost of developing new fields and the relevant discount rates. The estimation of these parameters is possible, but the results would be highly uncertain.

The demand for Russian natural gas is determined by preferences for natural gas, the prices of substitutes such as oil and gas from competitors, the cost of transporting gas within Western Europe etc. Most of the gas sold in Europe is based on a small number of long-term "take-or-pay" contracts, the details of which are not made public. The annual figures for average gas prices given in the statistics largely reflect oil-price movements to which contract prices are indexed. Consequently, there is little information on the demand side to allow an econometric estimation of the demand function.

Moreover, gas imports to Western Europe do not originate from Russia alone; there are other major suppliers such as Norway and Algeria. Consequently, the residual demand for Russian gas is defined as follows:  $Q_R = Q_M - (Q_N + Q_A)$ , where  $Q_M$  denotes market demand, and  $Q_N$  and  $Q_A$  are quantities supplied by Norway and Algeria respectively.<sup>5</sup> The price elasticity of residual demand facing a single supplier is higher (in absolute values) than the elasticity of demand for the market, because customers may switch from one gas supplier in

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<sup>5</sup> Assume Russia, Norway and Algeria act like Cournot players in the European natural gas market. In Nash equilibrium, player  $i$  conjectures that each rival supplies a given quantity and does not react to the marginal changes of volume of player  $i$ . (Lars Mathiesen 2008). That is, Russia conjectures that Norway supplies  $Q_N$  and Algeria  $Q_A$ , and furthermore that

$$\frac{\partial Q_N}{\partial Q_R} = 0 \text{ and } \frac{\partial Q_A}{\partial Q_R} = 0.$$

the market to another. There is in general little consensus in the literature concerning the price elasticities in energy markets, and estimated elasticities for Russia are almost non-existing. The elasticities that have been estimated vary and are primarily obtained for member countries of the OECD. In the survey by Al-Sahlawi (1989) on price and income elasticities of natural gas demand, short-run price elasticities range from -0.07 to -0.63 and long-run price elasticities range from -0.56 to -4.6.<sup>6</sup>

Given the lack of solid data, I choose to use demand and marginal cost of supply functions estimated in Hubert & Ikonnikova (2009). For simplicity they take linear specification for residual demand and marginal cost of supply and assume that they are independent of the transport route. The parameters of the functions have been chosen in order to capture the situation in the first years of the new century with respect to observed prices and quantities. The following numerical functions are obtained:

Marginal cost of supply at Russian export node:

$$mc_0(x) = 11[\$/\text{tcm}] + 0.8[\$/\text{mcm/a}] \cdot x[\text{bcm/a}]$$

$$\text{Inverse demand: } p(x) = 160[\$/\text{tcm}] - 0.33[\$/\text{mcm/a}] \cdot x[\text{bcm/a}]$$

The estimated functions yield reasonable figures for prices and elasticities at observed quantities. Given the capacities of 98 bcm/a, the estimated function for residual demand for Russian gas in Western Europe yields a price of 127 \$/tcm. This is consistent with the price of approximately 125 \$/tcm paid in the European Union in 2002 as reported by British Petroleum (2006).

With the price of 127 \$/tcm and the quantities equal to 98 bcm/a, the price elasticity of natural gas demand is calculated as follows:

$$\varepsilon(98) = \frac{\partial Q}{\partial P} \cdot \frac{P}{Q} = -\frac{1}{0.33} \cdot \frac{127}{98} = -3.93$$

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<sup>6</sup> Sagen, Erik Lund and Marina Tsygankova (2007): *Russian natural gas exports – Will Russian gas price reforms improve the European security of supply?* Statistics Norway, Research Department.

The price elasticity of residual demand for Russian gas is almost -4. As mentioned previously, the price elasticity of residual demand facing a single supplier is much higher (in absolute values) than the price elasticity for the market, which becomes apparent when comparing the obtained price elasticity of -3.93 with the elasticities reported by Al-Sahlawi (1989).

Most importantly, the parameters of the functions have been chosen so that the coalition of all players would maximize its profits by using existing capacities at *South* and *Yamal 1*, 70 bcm/a and 28 bcm/a respectively, while abstaining from investments in new capacities. A simple calculation can help to understand the reasoning behind this. Given a declining demand function coupled with a rising marginal cost of production function, the profit function is strictly concave. The maximum profit is obtained at the quantity where marginal cost of production equals marginal revenue, i.e. the quantity that gives zero marginal profit.

$$MC = MR$$

$$11 + 0.8x = 160 - 66x$$

$$x = 102$$

The profit maximizing quantity of the grand coalition is 102 bcm/a, which is very close to the existing capacities of 98 bcm/a. Hence, there would be no commercial interest to increase capacity.

## 4. Calculations – A Simple Example

With the purpose of making it easier for the reader to understand how the Shapley value approach can be applied in order to derive the power of the different players along the supply chain for Russian gas, I want to start this section by giving a short but thorough presentation of the main steps of the calculations of the Shapley value. In order to make the presentation as simple and logical as possible, I use a simplified version of the model where I assume that the profits available to the various coalitions are proportional to the existing capacities, while I disregard the costs of the pipelines and the production cost. The model reflects the short-sighted scenario of the game, where existing capacities consist of the pipelines *South* and *Yamal I*.

As explained earlier, the Shapley value, which is a player's expected contribution to all possible coalitions, can be derived as follows:

$$\phi_i(v) = \sum_{K \subset N} [v(K) - v(K \setminus \{i\})] \frac{(k-1)!(n-k)!}{n!}$$

where the first term in the summand is the marginal contribution of player  $i$  to coalition  $K$  and the second gives the probability of coalition  $K$  including player  $i$ .

First, I calculate the marginal contribution of each player to the various coalitions of the game. The calculations are presented in table 2.

Next, I calculate the probability of each coalition. The probability of a coalition consisting of two players, such as  $K(\{R, U\})$ ,  $K(\{R, B\})$  and  $K(\{U, B\})$ , is:

$$P(n, k) = \frac{(k-1)!(n-k)!}{n!} = \frac{(2-1)!(3-2)!}{3!} = \frac{1}{6}$$

The probability of a grand coalition consisting of all the players in the game,  $K(\{R, U, B\})$ , is:

$$P(n, k) = \frac{(k-1)!(n-k)!}{n!} = \frac{(3-1)!(3-3)!}{3!} = \frac{1}{3}$$

The probability of a player not joining any of the coalitions, i.e. the player chooses to act on his own, is:

$$P(n, k) = \frac{(k-1)!(n-k)!}{n!} = \frac{(3-1)!(3-3)!}{3!} = \frac{1}{3}$$

Table 2: Marginal Contributions

$K$	$i$	$v(i)$	<i>marginal contributions</i>
{R,U}	R	$v(\{R\})$	$v(\{R,U\}) - v(\{U\}) = 70 - 0 = 70$
	U	$v(\{U\})$	$v(\{R,U\}) - v(\{R\}) = 70 - 0 = 70$
	B	$v(\{B\})$	The player does not belong to the coalition.
{R,B}	R	$v(\{R\})$	$v(\{R,B\}) - v(\{B\}) = 28 - 0 = 28$
	U	$v(\{U\})$	The player does not belong to the coalition.
	B	$v(\{B\})$	$v(\{R,B\}) - v(\{R\}) = 28 - 0 = 28$
{U,B}	R	$v(\{R\})$	Player R is essential in the game. Coalitions which do not include R cannot form a complete supply chain.
	U	$v(\{U\})$	
	B	$v(\{B\})$	
{R,U,B}	R	$v(\{R\})$	$v(\{R,U,B\}) - v(\{U,B\}) = 98 - 0 = 98$
	U	$v(\{U\})$	$v(\{R,U,B\}) - v(\{R,B\}) = 98 - 28 = 70$
	B	$v(\{B\})$	$v(\{R,U,B\}) - v(\{R,U\}) = 98 - 70 = 28$

The final step is to calculate the Shapley value for each player participating in the game. By summing up the marginal contributions of the players to all possible coalitions of the game, while taking care of relative probabilities, I obtain the Shapley value – a share of the total profit allocated to each player. For example, the Shapley value for Russia is calculated as follows:

$$\phi_R = \frac{1}{3} v(\{R\}) + \frac{1}{6} (v(\{R,U\}) - v(\{U\})) + \frac{1}{6} (v(\{R,B\}) - v(\{B\})) + \frac{1}{3} ((v(\{R,U,B\}) - v(\{U,B\})))$$

The Shapley values for all players participating in the game are presented in the table 3. The relative size of payoff (in percent) indicates the strength of the player's position and is referred to as the player's power index.

Table 3: Relative Shapley Value [%]

$K$	$v(K)$	$P(K)$	$v(\{R\})$	$v(\{U\})$	$v(\{B\})$	<i>explanation</i>
$\{R\}$	0	1/3				No player can obtain profit alone.
$\{U\}$	0	1/3				
$\{B\}$	0	1/3				
$\{R,U\}$	70	1/6	70	70		The two participants have equal imputations.
$\{R,B\}$	28	1/6	28		28	
$\{U,B\}$	0	1/6				The coalition cannot form a complete supply chain.
$\{R,U,B\}$	98	1/3	98	70	28	
Shapley value, $\phi_i$			49	35	14	Summing imputations taking care of relative probabilities.
Power index			50,0 %	35,7 %	14,3 %	Relative imputations.

The results can be interpreted as follows. Russia obtains half of the total profit, while Ukraine and Belarus share the other half. The unequal shares of Ukraine and Belarus, 35.7% and 14.3% respectively, reflect the differences in capacities at *South* and *Yamal I.*

## 5. Results

### 5.1 The Power Structure in the Supply Chain for Russian Gas

The aim of the example given above, which was based on the assumption that the profits available to the various possible coalitions of the game are proportional to the installed transmission capacities, was to give a simple presentation of how the Shapley value can be derived for different players participating in a game. In the following I operate with a fully calibrated model (described in section 3.2 “Calibration”) which captures the costs of alternative pipelines, demand for gas and production and transportation costs. The profit which a particular coalition can achieve, i.e. the value of a coalition  $K$ , is calculated according to:

$$v(K) = p(x)x - C_0(x) - \sum_{l \in L_K} T_l x_l$$

where  $L_K$  denotes the pipeline options available to coalition  $K$ ,  $x_l$  is the quantity delivered through link  $l$ ,  $x$  is total supply,  $T_l$  stands for link specific transportation cost per unit of gas,  $p$  is inverse demand for Russian gas, and  $C_0$  denotes production cost.

In the following I use the Shapley value approach to calculate the relative power of the different players along the supply chain for Russian gas for various assumptions on the scope of the game.

#### “Status Quo” Game

The “status quo” game represents the short-sighted scenario, where the existing gas network consisting of *South* and *Yamal 1*, 70 bcm/a and 28 bcm/a respectively, cannot be changed. Furthermore, there would be no commercial interest to increase capacity as, given my assumptions on demand and supply, the existing capacities are close to the optimal (see section 3.2 “Calibration”). Consequently, the power of a player is determined by his control over installed pipelines.



Table 4: Relative Shapley value for the “Status Quo” Game

$K$	capacity	max sale	revenue	prod. cost	transp. cost	profit	$v(K)$	$P(K)$	$v(\{R\})$	$v(\{U\})$	$v(\{B\})$
$\{R\}$	0	0	0	0	0	0	0	1/3			
$\{U\}$	0	0	0	0	0	0	0	1/3			
$\{B\}$	0	0	0	0	0	0	0	1/3			
$\{R,U\}$	70	70	9583	2730	434	6419	6419	1/6	6419	6419	
$\{R,B\}$	28	28	4221	622	71	3529	3529	1/6	3529		3529
$\{U,B\}$	0	0	0	0	0	0	0	1/6			
$\{R,U,B\}$	98	98	12511	4920	620	6971	6971	1/3	6971	3443	553
Shapley value, $\phi_i$									3982	2217	772
Power index									57,1 %	31,8 %	11,1 %

In this situation, Russia completely depends on Belarus and Ukraine for transit. If the only possible transport route were through Ukraine, then Russia and Ukraine would share the profits 50%-50%. However, with the construction of *Yamal 1*, Belarus emerged as a competitor to Ukraine. The two countries compete for transit service, but the competition remains limited as the countries' capacities are restricted. Ukraine suffers a lot from the competing route, as it loses 36.4% of the profit it would receive as being the only transit country. Russia obtains 57%, which is just 7 points more than the 50% that it would receive if facing a monopolistic transit country. The unequal shares of Ukraine and Belarus, 31.8% and 11.1% respectively, reflect the differences in capacities at *South* and *Yamal 1*.

### “All Options” Game

However, the picture changes significantly when I take into account the various possibilities to modify the pipeline network – the situation which reflects the far-sighted scenario of the game. On its own, Russia would choose *Nord Stream*, the only option for which it does not need partners. Russia and Ukraine together forgo investment in *Nord Stream* and rather choose to upgrade the existing system *South*, which is the cheapest option for creating new capacities. This may seem surprising as one would expect the coalition to install the large capacities of *Nord Stream* in order to increase sales. However, it should be noted that given my assumptions on demand and supply, the profit maximizing quantity of the coalition is 102 bcm/a. Consequently, the costly investment in the *Nord Stream* pipeline would be considered excessive, as the coalition will not be able to sell almost a half of the additional

quantities. By abstaining from the project and in stead choosing to upgrade the depreciated system in Ukraine, the coalition avoids the high cost of *Nord Stream* while it obtains low cost capacities of 15 bcm/a at *South*.

Table 5: Relative Shapley Value for the “All options” Game

$K$	capacity	max sale	revenue	prod. cost	transp. cost	profit	$v(K)$	$P(K)$	$v(\{R\})$	$v(\{U\})$	$v(\{B\})$
$\{R\}$	55	55	7802	1815	2878	3109	3109	1/3	3109		
$\{U\}$	0	0	0	0	0	0	0	1/3			
$\{B\}$	0	0	0	0	0	0	0	1/3			
$\{R,U\}$	140	85	11216	3825	489	6901	6901	1/6	6901	3793	
$\{R,B\}$	111	83	11007	3669	3026	4313	4313	1/6	4313		1204
$\{U,B\}$	0	0	0	0	0	0	0	1/6			
$\{R,U,B\}$	196	98	12511	4920	620	6971	6971	1/3	6971	2659	70
Shapley value, $\phi_i$									5229	1518	224
Power index									75,0 %	21,8 %	3,2 %

Given that Russia's access to the Polish section of *Yamal 1* is secured, the coalition of Russia and Belarus would use the existing 28 bcm/a of *Yamal 1* and install a capacity of 55 bcm/a at *Nord Stream*, while abstaining from investment in the second string of the Yamal pipeline. Even though the capacity cost of the offshore pipeline is twice as large as the cost of *Yamal 2*, this investment option would provide substantial additions to the coalition's capacities without strengthening Belarus's strategic position. None of the additional investment options would be used by the grand coalition of all players as the existing capacities are very close to the profit maximizing quantity of 102 bcm/a. Hence, there would be no commercial interest to increase capacity. The Shapley value results of the “all options” game show that Russia obtains three fourths of the total profit – a 30% increase of the profit compared to the “status quo” game. The shares of Ukraine and Belarus are down to 21.8% and 3.2% respectively.

It should be noted that the choice of pipeline options available to the various coalitions of the game depends on the profit maximizing quantity of the grand coalition. Should the demand for Russian gas increase, resulting in a higher optimal quantity, the coalitions may choose differently. In the case where the demand is high enough to justify investment in the *Nord Stream* pipeline, both the grand coalition and the coalition of Russia and Ukraine would choose to install the capacities of *Nord Stream* in order to increase sales. This will further

strengthen Russia's strategic position in the game as an even larger share of the total profit would be allocated to the Russian supplier.

### The Strategic Value of Pipeline Options

To assess the strategic value of each investment option, I add one option at a time to the benchmark case "status quo" game and evaluate the changes it gives in the power structure. (A more detailed analysis of each investment option can be found in the appendix.) As mentioned previously, upgrading the depreciated transmission system in Ukraine provides the cheapest way to increase transport capacity. Hence, *Upgrade* is commercially the most interesting investment option for small additions to the capacity.

Table 6: Relative Shapley Value [%]

players	status quo	adding one option at a time			all options
		<i>Upgrade</i>	<i>Yamal 2</i>	<i>Nord Stream</i>	
Russia	57,1 %	58,2 %	61,7 %	73,9 %	75,0 %
Ukraine	31,8 %	33,0 %	22,6 %	20,6 %	21,8 %
Belarus	11,1 %	8,8 %	15,7 %	5,5 %	3,2 %

However, it has small impact on the power structure because the existing capacities at *South* are already large. The *Yamal 2* pipeline, which is the second cheapest option for creating new capacities, would have a substantial impact on the power structure. This investment option weakens Ukraine's position in the competition for transit service, and consequently reduces the country's share by more than 9 points, which is almost a third of the share in the "status quo" game. *Nord Stream*, the pipeline that would provide Russia with a direct access to its customers in the West, has the strongest impact on the power structure. It raises Russia's power index from 57.1% to 73.9%, while it cuts Ukraine's and Belarus's shares by 11.2 and 5.6 points respectively. The strategic importance of *Nord Stream* explains Russia's interest in the project, which from a commercial point of view makes little economic sense due to its high cost.

## 5.2 Summary of the Results

In this thesis I have used cooperative game theory, the Shapley value, to develop and calibrate a model of the power structure in the supply chain for Russian gas. The bargaining

power of the different players along this supply chain is derived endogenously from the architecture of the transmission system and its possible extensions. The power structure thus obtained reflects the essential economic futures, such as different cost of alternative pipelines, demand for gas, production costs, etc.

In general it is difficult to make use of the Shapley value in applied research. In order to calculate it, one must be able to calculate the profits of each possible coalition, the number of which grows rapidly as the number of players increases. Furthermore, the probabilities of the various possible coalitions may be very different from the situation prevailing in reality. As already discussed in section 3.1 “Theory”, all coalitions of the same size are regarded as equally likely in the Shapley value approach, which may not be the case in reality. This raises the problem of obtaining data and making predictions for rather hypothetical situations – which severely limits the practical applicability of the concept. Probably there are only a few markets for which there is enough information available, so that it is possible to calculate the profits for “unreal” situations with reasonable accuracy.<sup>7</sup>

Fortunately, the number of players in the supply chain for Russian gas is small and the investment options available to the various coalitions can be easily derived from the geography of the pipeline network. Moreover, all projects which have been considered in this thesis have already been proposed in one form or another – often with detailed cost estimates. In this sense, the Eurasian gas transmission system offers a good opportunity to assess the usefulness of the Shapley value in applied research.

Taking into account three options to extend the transmission system, I obtain a picture of the overall distribution of profits in the supply chain. The Shapley value approach allows me to evaluate the strategic impact of each single investment option on the power structure as well as it helps to understand the historical development of the gas network. The post Soviet development of the transmission system reflects to a large degree Russia’s attempts to strengthen its strategic position with regard to the transit countries – in particular Ukraine. In the case of pipelines, most of the investment in transport infrastructure is sunk and major players are independent nations, which leads to a substantial risk of opportunistic recontracting. Since the disintegration of the Soviet Union, Ukraine has engaged in several

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<sup>7</sup> Hubert, Franz and Svetlana Ikonnikova (February 2003): *Strategic Investment and Bargaining Power in Supply Chains: A Shapley Value Analysis of the Eurasian Gas Market*. First draft.

gas disputes with Russia, leveraging its strategic positions in the supply chain in order to gain concessions for its own gas imports. Although the renovation and upgrading of the old transmission system in Ukraine would provide a cheap way to increase capacity, the investment has not been undertaken in the past, as the country is considered to be a player who cannot credibly commit to adhere to long-term agreements. The *Yamal 1* pipeline was built with the purpose of reducing Ukraine's powerful position in the supply chain. The option to extend the *Yamal* pipeline, which is also commercially attractive, would further reduce the bargaining power of Ukraine and increase the competition between the two transit countries. However, by far the strongest impact on the bargaining power is exerted by *Nord Stream*. Although this project cannot compete commercially with the other options to increase transmission capacity, it strengthens Russia's position dramatically by allowing for lower capacity utilisation rates of the existing transit routes.

Plans for a direct offshore connection through the Baltic Sea do not only reflect Russia's desire to strengthen its strategic position vis-à-vis transit countries, but also serve as an answer to the increased energy needs of the European Union. *Nord Stream* would be an important contribution to security of supply as it would meet a quarter of additional import needs of Europe. However, concerned with the climate protection, the European Union has adopted several policies aimed at improvement of efficiency in energy production and use, and at development of renewable energy markets, which would have further consequences for energy markets. According to PROGRESS 2008, the avoided natural gas consumption due to new renewable energy capacities installed between 2005 and 2020 would equal 20% of total EU gas consumption in 2020. A growing role of renewable energy sources at the European energy market may lead to a lower demand for Russian gas in the future, which suggests that the *Nord Stream* pipeline may actually be superfluous, and that existing capacities could in fact be sufficient to meet the future demand.

On the supply side, the turmoil surrounding Russia's relations with the transit countries does not necessarily need to be the largest threat to stable Russian gas deliveries to Europe, as there are other critical issues within the Russian gas industry that need to be dealt with. There are several reasons for why Russia may not be the stable and dominant provider of gas that Europe for a long time has been accustomed to. In the next section of the thesis, I look more deeply into various factors that have potential to affect future supply and demand for Russian gas, and investigate whether the construction of *Nord Stream* may actually be superfluous.

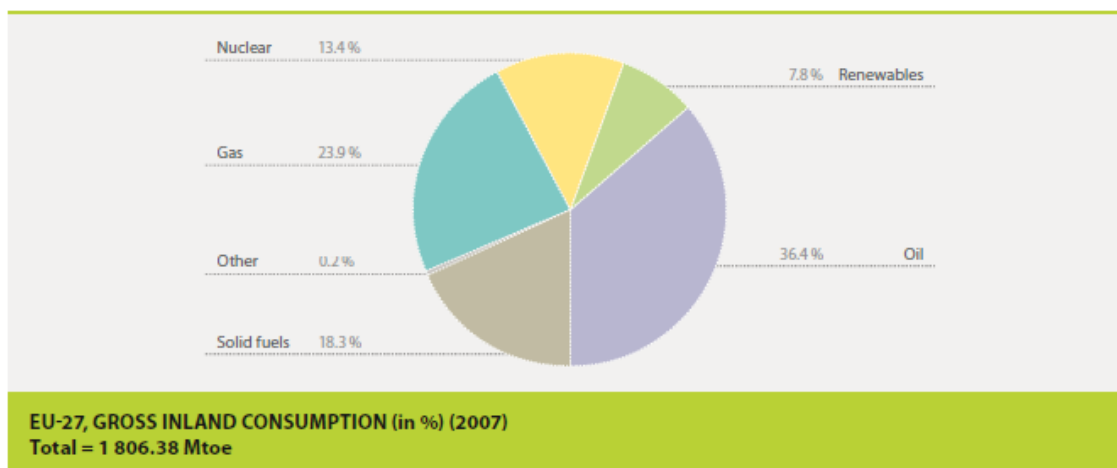
## 6. Can Nord Stream Be Superfluous?

### 6.1 European Gas Demand

#### 6.1.1 European natural gas market

It is difficult to generalise on natural gas use within the EU as gas production, supply and user infrastructure have been developed on the basis of individual countries' own reserves and in relation to diverse national energy policies. Hence, gas use tends to vary noticeably between countries. Still, some broad observations can be made. Natural gas has been an important source of energy diversity in EU energy supply, growing from 18% of energy mix in 1990 to 24% in 2007. Today, natural gas remains the second most used energy source in the EU. Gas covers some 28% of EU industrial energy needs, and more than one third of residential and commercial needs, being especially important in space heating.

**FIGURE 2**



Source: Europe's Energy Position: Markets and Supply (2009)

EU natural gas production peaked in 1996, plateauing until around 2004, and has since been falling in line with its mature status, indicating that European gas fields are becoming depleted. According to IEA (2008), EU production has dropped by around 12% during the period 2005-2007, and is projected to fall further to the point where 2020 output is expected to be about 56% of 2004 production.

Gas imports have been an important feature of Europe's gas supply for some decades. By 2007, the EU imported 60.3% of gas consumption. The three main suppliers of natural gas to the EU in 2007 were Russia (41% of imports), Norway (27%) and Algeria (17%). Russia is by far the most important exporting country to the EU, while Europe is the most important destination for Russia's energy exports.

Gas is projected to play a growing role in meeting EU energy needs and in relationship with the electricity sector. Gas has become the preferred choice for new power plant investment in most EU countries. National policies in some European countries are strong drivers for this development, such as the politically determined early phase-out of nuclear power in Germany, Belgium, Spain and Sweden. Gas is also favoured over coal and oil for its lower emissions, especially of carbon dioxide.

Gas-fired power generation has many advantages that make it attractive to investors. Gas-fired plants have lower capital costs and shorter construction time than most other technologies, at the same time as they are very efficient at converting primary energy into electricity. Moreover, the operating flexibility of these plants makes them the preferred choice to meet Europe's increasingly peaky and seasonal power demand. IEA (2008) expects EU gas imports to rise further, from 63% of supply in 2010 to 77% in 2020.

The share of Russian hydrocarbons on the EU market is projected to remain high in the future, considering not only the geographical proximity of Russia and the EU but also the large Russian reserves of hydrocarbons and falling domestic production from the EU's North Sea oil and gas fields.

### **6.1.2 Climate Protection - The Policies of the European Union**

Future development of gas demand in Europe relies heavily on growing awareness of environmental concerns and related regulations. As the latest scientific evidence suggests, the pace of climate change resulting from man-made emissions of greenhouse gases — the bulk of which come from burning fossil fuels — is faster than predicted. The urgent need for a veritable energy revolution, involving a wholesale global shift to low-carbon technologies, is now widely recognised. Governments worldwide are concerned with finding a way of supplying the world's growing energy needs in a way that does not irreparably harm the environment.

Because climate protection is one of the focal points of the EU's policies, a comprehensive policy package was agreed on in 2007, leading to proposals for new EU legislation and measures from the European Commission. These include binding targets to reduce greenhouse gas emissions by 20% compared to 1990 levels, increase the share of renewable energy in the gross final energy consumption to 20% and non-binding target to reduce energy consumption by 20%, all by 2020. Moreover, in December 2008 EU leaders agreed a new directive which breaks the overall 20% renewable energy sources (RES) target down into individual binding Member States targets. Member States will have now to consider the best option to attract investment and support the development of RES in a cost efficient way, taking into account the differences between each sector.

In order to reduce greenhouse gas emissions in a cost-effective manner, the EU Countries have agreed to set up an internal market enabling companies to trade carbon dioxide pollution permits. In January 2005, The European Union Emission Trading Scheme (EU ETS) commenced operation as the largest multi-country, multi-sector greenhouse gas emission trading system in the world. Under this scheme, some 10,000 energy intensive plants across the EU are required to buy and sell permits to release carbon dioxide into the atmosphere. Market based instruments such as the EU ETS will be a key tool to ensure that Europe and other countries reach their targets at least cost. Carbon penalties under the EU Emissions Trading Scheme help gas to compete against more carbon-intensive coal in the power sector and heavy industry, as switching from coal-fired to gas-fired power generation is often one of the cheapest options to reduce CO<sub>2</sub> emissions in the near term.

The EU's ultimate objective is to limit global average temperature increase to less than 2°C compared to pre-industrial levels. This will limit the impacts of climate change and the likelihood of massive and irreversible disruptions of the global ecosystem. According to the IPCC's *Fourth Assessment Report*, this will require atmospheric concentrations of greenhouse gas emissions to remain well below 550ppm (parts per million of CO<sub>2</sub> equivalent). A stabilisation of long-term concentrations at 450 ppm CO<sub>2</sub>-eq corresponds to a 50% chance of restricting the increase in global average temperature to around 2°C.

Stabilisation of greenhouse gas concentration at 450 ppm CO<sub>2</sub>-eq is also assessed in World Energy Outlook 2008 under the name "the 450 Policy Scenario". In this scenario global energy-related CO<sub>2</sub> emissions are expected to peak in 2020 and then begin a sharp, sustained decline. By 2030 global energy-related CO<sub>2</sub> emissions are assumed to fall by 8% relative to



2006. This would require much stronger and broader policy action from 2020 onwards, inducing quicker development and deployment of low-carbon technologies.

### **6.1.3 Renewable Energy Sources**

Increasing concerns over energy security and climate change, coupled with higher fossil-fuel prices, declining investment costs and government support, are expected to encourage the development of renewable energy for electricity production in many parts of the world. IEA (2008) projects electricity from renewable energy sources to overtake gas as the world's second-largest source of electricity behind coal before 2015, rising from 18% in 2006 to 23% in 2030. In the EU-27, RES consumption has almost doubled since 1990. RES remain the fifth source of EU gross inland consumption (energy mix) in 2007 with a share of 7.8%. A fast-growing market for renewable energy is to be expected in Europe given the large gap between actual RES deployment and the 20% target.

### **6.1.4 Summary of the Demand Side**

The share of Russian gas on the EU market is projected to remain high in the future, considering not only the geographical proximity of Russia and the EU but also the large Russian reserves of hydrocarbons and falling domestic production in the EU.

However, over the last decade, renewable sources of energy have received a significant boost as a result of policy and technology progress. Given the large gap between actual RES deployment and the 20 % target, a fast-growing European market for renewable energy is to be expected. The long-term fundamentals for RES development, such as climate change, are strong and should attract investment. As already experienced, the large roll-out of RES in energy infrastructure in the EU has not been left to the market alone. The binding EU-wide target to source 20% of EU energy needs from renewables by 2020, has created certainty for investors in renewable energy technologies.

Deploying RES infrastructure and developing RES markets at a larger scale will have further consequences for energy markets and in particular for electricity. The increased RES deployment in the 20% target case will reduce fossil fuel demand and thus is an important element in improving the security of energy supply in Europe. According to PROGRESS 2008, the avoided natural gas consumption due to new RES capacities installed between 2005 and 2020 would equal 20% of total EU gas consumption in 2020 or 24% of default gas

import needs. Consequently, the future development of gas demand in Europe relies heavily on the degree to which the EU succeeds in achieving the 20% target.

## 6.2 Supply of Russian Gas

### 6.2.1 The Production Capacity of Gazprom

Russia's resources are unquestionably large enough to support continuing long-term growth in production. Russia is the world's largest natural gas producer and exporter; one-quarter of the global gas reserves (48 tcm) are located in the country, and there are undoubtedly more to be discovered. However, there are doubts about the cost of developing those resources and the speed with which Gazprom and independent companies can proceed. The Russian gas industry is at a cross-roads as production shifts from the super-giant fields upon which Gazprom has almost exclusively depended for the last four decades to fields located in new, more difficult-to-develop regions which need new transportation infrastructure. Russia's three super-giant fields in western Siberia, Medvezhye, Urengoy and Yamburg, have all reached their decline phase of production. Output from these fields, which currently accounts for over 60% of Gazprom's production, is expected to fall in coming years. However, there are considerable doubts about the rate of production decline and the extent to which judicious investment could reduce it. The giant Shtokman gas field in the Barents Sea has vast gas deposits. Difficult mining conditions require huge upfront investments; hence the projected start-up from this field has been delayed.

Gazprom plans to offset partially these production declines in the next few years by raising output from a fourth super-giant gas field, Zapolyaroye. Gazprom is also planning to develop other deposits, mainly in western Siberia, over the next decade. It plans to prioritise the development of new, smaller associated satellite fields in the Nadym-Pur-Taz region in order to be able to make use of existing pipelines and compensate for inevitable production decline of the three main fields.

In order to compensate for the decline in the existing gas fields and avoid scarcity of production, massive investments in the Russian gas industry are needed. The cost of Russian gas will inevitably increase as production from old low cost fields declines and new, more expensive fields have to be developed.

## 6.2.2 Independent Producers

Gazprom dominates the Russian gas sector, accounting for over 60% of Russian reserves (almost 30 tcm) and almost 85% of Russian production. Gazprom owns the Russian gas transmission system and has a legal monopoly on gas exports. Being a state controlled company, Gazprom has obligations to meet the domestic demand at any price by either using its own production or allowing alternative supplies from independent producers to fill the potential gap.

The main non-market feature of the Russian economy inherited from the Soviet era is the low domestic gas prices. Domestic gas prices are regulated by the Russian government and are significantly lower than the prices Gazprom obtains from its sales to Western Europe, even after netting back exports and customs duties and transportation costs. The European gas market is the most profitable market for Gazprom despite the additional costs such as transit payments to Ukraine and Belarus. Hence, Gazprom would prefer to earn more on additional sales to export markets if other suppliers could cover more of the domestic market.

Besides Gazprom there is a small competitive fringe of gas suppliers represented by independent gas producers and major Russian oil companies that serve the domestic market, while Gazprom is the sole exporter of Russian gas. Oil companies and independent gas producers each account for another 20% of Russian gas reserves and produce the balance of total production. Formally, the price of independent gas producers is not regulated; hence they are free to charge their own price. However, the price at which the independent producers sell their gas is close to the regulated one. The independents have little leverage over price as their production is principally constrained by the permission of Gazprom to access the transmission pipelines connecting independent producers to the domestic market. Although Gazprom is legally obliged to offer the spare transportation capacity to third parties, few agreements have been reached, mainly because charges are considered prohibitive. Faced with a monopsony buyer, independents have no choice but sell their gas directly to Gazprom at low prices or flare it.

Although the non-Gazprom producers account for only 14% of total production, they have the potential to play an increasing role in the Russian natural gas industry as they control a significant share of Russia's natural gas reserves. But even though the production potential

of independent producers is high and the investment shortage is not an obstacle, independent producers are reluctant to initiate new projects that will increase their production capacity as long as Gazprom controls the market access through its pipeline ownership.

If Gazprom opens up for competition and grant the independent producers guaranteed access to markets, it would imply larger volumes of cheap (associated) gas available to the domestic market. It would also enhance Russian gas supply through improved pipelines operations, reducing leakage, and reduced flaring. Consequently, with independent producers covering a larger share of the domestic market, Gazprom would be able to reallocate more of its supplies towards Europe.

### **6.2.3 Investment and the Domestic Price Reform**

As described earlier, Russia's gas production in the future will increasingly depend on fields in much more difficult-to-develop and environmentally sensitive regions. Massive investments in Russian natural gas industry are needed to compensate for the decline of the West Siberian giants, to develop new fields and to build pipelines to connect them to the domestic network and export systems.

Gazprom lacks the financial ability to compensate for the production decline and to upgrade the aging transportation network. A critical uncertainty for the financial health of the gas industry and its capacity to finance capital spending is the governmental regulation of domestic gas prices, which remain well below full cost. A gradual price increase is one of the main elements in the Russian energy strategy, as it is believed to be essential to provide the necessary investments into the Russian gas industry. Gas prices are planned to rise gradually to Western European levels, so that domestic prices will be at "parity" with export prices less transportation and excise duty. At present, it seems likely that this strategy will be revised so parity is achieved not earlier than 2015.

The abolition of domestic price regulation would provide better incentives for domestic production and sales, reduced flaring and losses in pipelines. It will enable Gazprom to make profits on the Russian market that could be invested in new facilities. The Russian domestic gas market reforms may also have a substantial effect on the total amount of Russian gas sold in the European market, as domestic prices affect Russian gas demand and, therefore, the amount of gas that will be available for export. At higher domestic price levels, the

Russian demand response is negative, creating additional volumes for export markets. This is often described as the Russian natural gas bubble.

Both domestic price reforms and sufficient independent gas supplies seem to be essential for the Russian gas industry in the future. A failure to implement much-needed market reforms, including raising domestic prices to full-cost levels and giving independent producers access to Gazprom's monopoly national transmission system, could impede the financing of new projects and opportunities for the independents to develop their own reserves.

#### **6.2.4 The Role of Long-Term Contracts for the Allocation of Gazprom Supplies**

As mentioned previously, in the domestic market Gazprom has obligations to meet the demand at any price determined by the government or allow alternative sources of supply to fill the gap if necessary. Gazprom allocates its production of natural gas between the Russian domestic market at an exogenously regulated price, and the European export market, mostly determined by so called take-or-pay contracts. Historically, the Eurasian transmission system was developed under long-term agreements, typically ranging from 15 to 25 years, which regulated prices and quantities to ensure the efficient usage of the capacities and steady revenues. In these take-or-pay contracts, the buyer agrees to receive a certain volume of gas per year or, alternatively, to pay for the portion of gas he does not want to receive. Gas delivered at the long-term contract is priced according to a price formula that links the current gas price to the price of relevant energy substitutes, such as oil products. Gas prices are thus set at such a level that the relation between gas prices and oil product prices does not give gas users any incentive to switch to the alternative fuel. With the so-called netback market value concept, the price for the gas producers is derived from the end user prices for the cheapest alternative fuel. Consequently, fluctuations in oil prices are passed on to the producers of the gas. These long-term contracts include the possibility of price renegotiation to adjust to the oil price every three to six months.

Whereas LTCs remain important, their share and average contract duration will probably be gradually reduced. The EU aims to open up the natural gas market for more competition in all parts of the supply chain with the purpose of bringing gas prices down through increased competition. Moves to liberalise gas market in Western Europe are expected to lead to increased gas-to-gas competition and could ultimately exert downward pressure on Russian

export prices. Liberalisation is also likely to affect the terms and conditions of future long-term contracts. European merchant gas companies would seek contracts of shorter duration and more flexible pricing terms in response to the increased market risks they face. It is believed that the ongoing liberalization of the internal European gas market will gradually reduce the role of the long-term contracts in favour of more flexible short-term contracts and spot trade.

A study made by Sagen & Tsygankova (2007) investigates whether a fully competitive European gas market may provide incentives for Gazprom to change its export behaviour. Their findings suggest that the level of gas exports tied to LTCs may prove to be highly significant for Gazprom's allocation of gas sales in the future. A liberalised European export market, largely determined by more flexible short-term contracts and spot sales, seems to favour Gazprom in terms of possibilities to exercise market power in the European market. The rationale behind this finding is that export prices are more sensitive to additional exports when the share of flexible short-term markets is large. The results of the study show that in an oligopoly market place market players (in this case Gazprom) have incentives to hold back exports to maintain higher prices. As Gazprom faces increasing marginal costs for higher production levels, Sagen & Tsygankova (2007) find that Gazprom would hold back its total production to achieve optimal sales in both domestic and export markets. In the situation where domestic prices are not large enough to cover the costs, increased exports will lead to lower export prices than what is optimal for Gazprom. Hence, Gazprom would adjust its export volume to achieve optimal prices and revenues in its export market, and regulate independent supplies to achieve optimal revenues in the domestic market. The larger the sensitivity of export prices, resulting from a larger spot market, the larger are the incentives and willingness to use accessible market power to influence prices in that particular market. Sagen and Tsygankova (2007) conclude that only if domestic prices approach the netback levels of European market prices minus the cost of transport, overall export volumes move towards the peak export levels observed in a traditional LTC market structure. Otherwise Europe may actually have less imports of Russian gas.

### **6.2.5 Summary of the Supply Side**

The sufficiency of reserves in Russia is not an issue. However, coupled with stagnating production in existing fields, fast-growing domestic consumption, and increased export commitments, it leads to very uncertain projections for the near future. Russian gas

production is increasingly dominated by production from new, more difficult-to-develop regions requiring substantial investments in the Russian natural gas industry. In particular, the ability of Gazprom and other gas suppliers to finance new supply projects and their incentives to do so are highly dependent on the prices that they are able to achieve on both domestic and export markets. A combination of low Russian gas prices and low production capacity may be disastrous for the future flow of Russian gas. If Gazprom continues to be the domestic gas provider of last resort, scarce production capacities of both Gazprom and independent producers will restrict export volumes if the domestic market is given political priorities. Increased domestic gas prices from the present level will create improved export possibilities resulting from lower Russian gas demand and increased gas supplies from independent producers. Thus, for the European Union it can be particularly important that Russia is able to further increase domestic prices toward international market levels and thereby release large gas volumes for exports.

Furthermore, if Gazprom opens up for competition and gives independent producers guaranteed access to the national transmission system, it would encourage development and production from Russia's vast gas reserves and of associated gas.

Finally, liberalisation of the European gas market, enforced by the emergence of new contract mechanisms such as spot market, short-term or non-dedicated contracts, is likely to affect the terms and conditions of future long-terms contracts. If volumes of long-term contract are reduced, it might be optimal for Gazprom to reduce its exports in favour of domestic gas sales in order to achieve a balance between marginal revenues in both domestic and export markets. Thus, a liberalized European gas market may provide even less Russian exports in the future.

## 7. Conclusions

The future of Russian gas exports to Europe is subject to a wide range of uncertainties, notably about underlying demand, price and cost factors. Due to low regulated domestic gas prices and lack of investment in new gas fields and infrastructure, Russia might soon have problems balancing production, rising domestic demand and growing export commitments. Should there be a scarcity of gas, building *Nord Stream* might not be justified, as the capacities of existing pipelines should suffice to meet the European demand.

Future development of gas demand in Europe relies heavily on growing awareness of climate change and increased reliance on non-fossil fuels. The policies of the European Union, aimed at reduction of greenhouse gas emissions and increase of the share of renewable energy in the energy mix, provide incentives for investment in emission reduction technologies and low carbon alternatives. The increased deployment of the renewable energy sources will lead to a decline of fossil fuel demand in Europe. However, switching, from coal-fired to gas-fired power generation is often one of the cheapest options to reduce CO<sub>2</sub> emissions in the near term, depending on gas and coal prices. Therefore, gas-fired power is likely to play an important role in the targets of the European Union, providing a continued strong driver for gas-fired power generation in Europe. All these factors should be considered carefully when predicting future European demand for Russian gas.

In the case of lower demand, upgrading the capacity at *South* by 15 bcm/a could be justified, but expanding *Yamal* would not be warranted, whereas building the *Nord Stream* pipeline would be considered as a major overinvestment from a commercial point of view. However, using the Shapley value approach I found out that investment in the *Nord Stream* pipeline significantly increases Russia's bargaining power. Therefore, *Nord Stream* should be considered not only from a commercial point of view, but also as a strategic move. By installing large capacity in *Nord Stream*, Russia creates a countervailing power to Ukraine and Belarus. This offshore pipeline would allow Russia to use the capacities at *South* and *Yamal* to a lesser extent, a threat that is strong enough for Ukraine and Belarus not to exploit their bargaining positions to the full.

In the high demand case, all three investment options might be justified. Even though expanding the facilities in Ukraine and Belarus would strengthen these countries in ex-post negotiations, the investment in the *Nord Stream* pipeline would contribute to diversification



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of the supply routes and provide Russia with a countervailing power which will weaken the transit countries' strategic position in the supply chain.

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## APPENDIX A: Transportation Cost

The total cost of transport gas can be decomposed into capacity cost  $c$  and operating cost, the latter consisting of management and maintenance cost  $m$  and energy cost  $g$ . In order to obtain a realistic picture of the differences in transportation costs, these items are estimated for every possible link separately.

In the case of pipeline technology, the cost of providing transport capacity is roughly proportional to distance and the same applies to maintenance. However, energy cost, which to a large degree consists of the value of gas that is consumed by compressors, is more difficult to calculate because the price of gas increases along the way. As the fraction of gas used over a given distance is approximately constant, the marginal transportation cost of supplying gas through a particular link  $l$  can be calculated according to:<sup>8</sup>

$$t_l = \left( \frac{c_l + m_l}{g_l} + MC_0(x) \right) \cdot (e^{g_l \cdot y_l} - 1)$$

where  $y_l$  denotes the length of the pipeline,  $g_l$  is the fraction of the gas per distance which is needed for pressurizing, and  $MC_0$  is the marginal cost of production. The latter affects transportation cost because it determines the value of compressor gas. Note that the parameters  $m_l$ ,  $c_l$  and  $g_l$  refer to a particular link, while  $x$  refers to the aggregate quantity.

Given the marginal cost of production function estimated earlier,  $mc_0(x) = 11[\$/\text{tcm}] + 0.8[\$/\text{mcm/a}] \cdot x[\text{bcm/a}]$ , the total link specific transportation cost can be calculated as follows:

$$T_l = x \cdot \left( \frac{c_l + m_l}{g_l} + 11 + 0.4x \right) \cdot (e^{g_l \cdot y_l} - 1)$$

In the following I explain in detail how the different components of the transportation cost formula are obtained.

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<sup>8</sup> Hubert, Franz and Svetlana Ikonnikova (December 2007), p.34. The marginal cost of supplying gas through a particular link  $i$  is obtained according to:  $mc_i(x, y) = mc_0(x) e^{g_i y_i} + (e^{g_i y_i} - 1)(c_i + m_i) / g_i$ . By deducting the initial value of  $mc_0$ , the marginal cost of transportation is obtained.

## Capacity Cost

For existing pipelines, *South* and *Yamal 1*, capacity cost is sunk and thus can be ignored in the analysis. Regarding new projects, such as *Nord Stream* and *Yamal 2*, there are considerable variations in published cost estimates. Therefore, I complement published information with figures obtained from Hubert & Ikonnikova (2007) who estimate the cost of establishing the capacity for a complete link from a major node in the Russian system to the border of Western Europe. Cost of pipes, compressors and track preparations are estimated to reflect the situation in 2000.

For new pipelines, the capacity cost is roughly proportional to distance, however, there are economies of scale gained from laying pipelines along the same track. Some costs of preparing the ground, building supply roads, etc. can be avoided by using established tracks. Parallel pipelines also allow for sharing of compressor power and to economize on backup facilities. Finally, an isolated new pipeline has to cross the whole distance before supplying the first gas, while capacity along existing tracks can be increased gradually and therefore more timely adjusted to the growth of demand. As new pipelines need about three years for completion, 15% of investment cost for interest during construction is added in these cases.

The figures in the third column of table 7 show that the capacity costs vary considerably between the different investment options. For *South* and *Yamal 1* capacity cost is sunk, the *Upgrade* project has low capacity cost as it can make use of the existing infrastructure, while *Nord Stream* has the highest capacity cost. As all figures are expressed on annual basis, I calculate the annualized cost of capacity for each link  $l$  as follows:

$$C_l = \frac{I_l \cdot r}{1 - (1 + r)^{-T}}$$

where  $I_l$  is the project specific investment cost per capacity,  $T = 25$  denotes the expected lifetime of the facilities and  $r = 15\%$  is assumed interest rate for investment in the gas industry.

Finally, I calculate the annualized capacity cost per 100km for each link  $l$  by dividing the annualized capital cost of the link  $l$  by the total length of the link,  $c_l = C_l / y_l$ . The results are presented in the fourth column of table 7.

Table 7: Transport Links for Russian Gas

project	capacity (bcm/a)	length (100km)	capacity cost (\$/tcm)	annualized capacity cost (\$/tcm/100km)	management & maintenance (\$/tcm/100km)	compressor gas (%/100km)
<b>South</b>	70	20	sunk	sunk	0,1	0,50 %
	The old southern system in poor state of repair. Higher energy cost due to old compressors.					
<b>Upgrade</b>	15	20	50	0,39	0,1	0,25 %
	Repaires and replacement of old compressor stations using the existing pipeline capacities.					
<b>Yamal 1</b>	28	16	sunk	sunk	0,1	0,25 %
	Pipeline from Torzok to Germany, operating since 1999.					
<b>Yamal 2*</b>	28	16	99	0,95	0,1	0,25 %
	New pipeline parallel to <i>Yamal 1</i> with some preparations already made.					
<b>Nord Stream*</b>	55	16	215	2,78	0,2	0,50 %
	New pipeline from Greifswald (Germany) - Vyborg (Russia) 1200km offshore, then 400km onshore to Torzhok. Higher maintenance cost due to large offshore section, and higher energy cost due to higher pressure.					

\* As these are new projects which take considerable time to complete, investment costs are increased by 15% to account for interest during constraction.

## Operating Cost

The cost of management and maintenance,  $m_i$ , is assumed to be proportional to distance and quantity of gas, and equal to  $m_i = 0.1\$/\text{tcm}/100\text{km}$  for all pipelines, except the offshore pipeline *Nord Stream*, for which the figure is doubled due to the pipeline's large offshore section. To keep the gas moving, a certain fraction  $g$  of it is used to power compressor stations. Energy cost is assumed to be  $g = 0.25\%/100\text{km}$  for all pipelines, except for *South* and *Nord Stream*. As the compressors at *South* are old and inefficient and because *Nord Stream* needs much higher pressure for its offshore section, both links have  $g = 0.5\%$ .

## APPENDIX B: The Strategic Value of Pipeline Options

Calculations behind the Shapley value results presented in section 5. “Results” can be found in this appendix. I also explain the choice of capacities for each coalition.

### Upgrade

Table 8: Relative Shapley value - *Upgrade*

$K$	capacity	max sale	revenue	prod. cost	transp. cost	profit	$v(K)$	$P(K)$	$v(\{R\})$	$v(\{U\})$	$v(\{B\})$
$\{R\}$	0	0	0	0	0	0	0	1/3			
$\{U\}$	0	0	0	0	0	0	0	1/3			
$\{B\}$	0	0	0	0	0	0	0	1/3			
$\{R,U\}$	85	85	11216	3825	489	6901	6901	1/6	6901	6901	
$\{R,B\}$	28	28	4221	622	71	3529	3529	1/6	3529		3529
$\{U,B\}$	0	0	0	0	0	0	0	1/6			
$\{R,U,B\}$	113	98	12511	4920	620	6971	6971	1/3	6971	3443	70
Shapley value, $\phi_i$									4062	2298	611
Power index									58,2 %	33,0 %	8,8 %

In this game, the option to upgrade the existing system *South* is available to coalitions which include Ukraine. Russia and Ukraine together choose to invest in *Upgrade* as it will bring the coalition’s capacities closer to the optimal quantity of 102 bcm/a. The grand coalition of all players will forgo investment in *Upgrade*, as the existing capacities of the coalition are already close to the optimal.

### Yamal 2

The option to build the second string of the Yamal pipeline is available to coalitions which include Belarus. The coalition of Russia and Belarus would use the existing 28 bcm/a of *Yamal 1* and install a capacity of 28 bcm/a at *Yamal 2* in order to increase sales. The grand coalition will abstain from investment in *Yamal 2* as the existing capacities are sufficient to maximize the coalition’s profits.



Table 9: Relative Shapley value - *Yamal 2*

$K$	capacity	max sale	revenue	prod. cost	transp. cost	profit	$v(K)$	$P(K)$	$v(\{R\})$	$v(\{U\})$	$v(\{B\})$
$\{R\}$	0	0	0	0	0	0	0	1/3			
$\{U\}$	0	0	0	0	0	0	0	1/3			
$\{B\}$	0	0	0	0	0	0	0	1/3			
$\{R,U\}$	70	70	9583	2730	434	6419	6419	1/6	6419	6419	
$\{R,B\}$	56	56	7925	1870	603	5451	5451	1/6	5451		5451
$\{U,B\}$	0	0	0	0	0	0	0	1/6			
$\{R,U,B\}$	126	98	12511	4920	620	6971	6971	1/3	6971	1520	553
Shapley value, $\phi_i$									4302	1576	1093
Power index									61,7 %	22,6 %	15,7 %

## Nord Stream

Table 10: Relative Shapley value - *Nord Stream*

$K$	capacity	max sale	revenue	prod. cost	transp. cost	profit	$v(K)$	$P(K)$	$v(\{R\})$	$v(\{U\})$	$v(\{B\})$
$\{R\}$	55	55	7802	1815	2878	3109	3109	1/3	3109		
$\{U\}$	0	0	0	0	0	0	0	1/3			
$\{B\}$	0	0	0	0	0	0	0	1/3			
$\{R,U\}$	125	70	9583	2730	434	6419	6419	1/6	6419	3310	
$\{R,B\}$	83	83	11007	3669	3026	4313	4313	1/6	4313		1204
$\{U,B\}$	0	0	0	0	0	0	0	1/6			
$\{R,U,B\}$	153	98	12511	4920	620	6971	6971	1/3	6971	2659	553
Shapley value, $\phi_i$									5149	1438	385
Power index									73,9 %	20,6 %	5,5 %

The option to invest in the offshore *Nord Stream* pipeline is available to coalitions which include Russia. On its own, Russia would choose *Nord Stream*, the only option for which it does not need partners, and install a capacity of 55 bcm/a. Russia and Ukraine together would avoid the high cost of *Nord Stream*, the capacity of which would be considered excessive given my assumptions on demand and supply. The coalition of Belarus and Russia, would use the existing 28 bcm/a of *Yamal 1* and invest in *Nord Stream*, thereby obtaining a total capacity of 83 bcm/a. The grand coalition of all players will forgo

investment in *Nord Stream* as the existing capacities suffice to achieve the profit maximizing quantity.