

# **Russian Gas to Western Europe**

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## **A Game-theoretic Analysis**

**Diploma Thesis**

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Zurich, 18 May 2006

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# 1. Introduction

Russia is the most important supplier of gas worldwide and especially for Europe. At the time of the Soviet Union, transportation and routing was no big issue, since there was no third party in between. This changed when the Soviet Union collapsed. Newly independent states became indispensable parts of the Eurasian gas chain and changed the situation dramatically for the producer. The transit countries, Ukraine and Belarus, seek to profit from their geographical location whereas Russia wants cheap and reliable transport routes to sell its gas on the Western European markets. What position are the different countries facing in the gas transit game? What is their bargaining power when negotiating with one another over transit fees? What are the different new projects in the gas chain and how do they change the players' situation? What coalitions are possible and which strategy promises the highest payoff for the players? These questions are addressed in this paper.

This situation can be modeled as a gas transit game with the players Russia, Ukraine and Belarus. Game theory provides good tools to analyze interactions of players with different goals and possibilities. I will use the methods of cooperative game theory to derive the players' bargaining power and the outcomes of the cooperative scenarios. The calculations are made for three different points in time, viz. 2004, 2010, and 2030. As 2004 is the most recent year with available data, it represents the current situation, whereas 2010 gives an outlook for the near future and 2030 for the mid-term future. Further on, I will use standard non-cooperative game theory to calculate the non-cooperative results for the same years, by including the obtained bargaining powers. Analyzing the results, one can see the impact of various changes in the gas chain. This can be useful for these players when deciding about actions, investments or cooperation.

First research in this direction was done by Grais & Zheng (1996), who modeled a Stackelberg game with Russia as leader and the transit countries, Ukraine and Czechoslovakia, as followers. A similar approach, with Belarus instead of Czechoslovakia, comes from Hirschhausen et al. (2005), where non-/cooperative scenarios are calculated for different routes. Finally, Hubert and Ikonnikova (2003) analyze the strategic behavior of the players and determine their bargaining power by using the Shapley value.

Section 2 summarizes the historical development of the transport routes, describing the specific circumstances of the involved countries and their relation to one another. This is important for understanding the current behavior of these countries and for predicting possible future actions. In section 3 the transit game is modeled and the assumptions explained. The

cooperative scenarios and the bargaining powers are compiled in section 3.1 and in 3.2 all non-cooperative scenarios. The data and results are presented in section 4, whereas subsection 4.1 contains the outcomes of the cooperative model by period. Section 4.2 does the same for the non-cooperative model, featuring tables with the results of all possible coalitions for comparison. A deeper analysis is presented in section 4.3, where optimal strategies for each player are explained and justified. Finally, section 5 contains a summary with conclusions and concluding remarks.

## **2. The Eurasian gas chain**

### **2.1 Historical Development of Transport Routes**

Compared to coal and oil, natural gas has started being traded internationally only recently. Since the middle of the 20<sup>th</sup> century, gas exports have seen a continuous increase in volume. Even political and ideological borders could not prevent the gas from finding its way from the producer to the consumer. The best example is the former Soviet Union, who started to deliver gas to Western Europe during the cold war, with the first pipeline connection to Austria in 1968 and West Germany in 1973 (Stern, 2005).

At that time, no independent countries stood between the producer and the consumer. Almost all gas passed through one huge export pipeline, called Brotherhood. This pipeline goes from Russia through the Ukraine, which was also part of the Soviet Union, to former Czechoslovakia, which was highly dependent from the Soviet Union. From there, the western markets are easily reached (Hubert & Ikonnikova, 2004). In the Soviet Union, the gas industry was not an independent economic entity but a government body where actions were driven by politics (Hirschhausen v. & Engerer, 1998). So, even when gas production shifted from the southern Ural northwards to western Siberia, the export route remained in the south. A new export route in the north, from Belarus through Poland and East Germany was economically feasible, but Moscow decided that Czechoslovakia was politically more reliable at that time.

After the collapse of the Soviet Union, Russia found itself in an unfavorable situation. The only viable export route to the west went through the newly independent states Ukraine, Slovakia, and Czech Republic. This turned the once bilateral gas export game between the Soviet Union and Western Europe into a multi-player game with several different outcomes. These independent countries inherited a quasi-monopolistic position for gas transport, and

some sought to profit from it. Slovakia and the Czech Republic never capitalized on this fact because they were looking for integration with the EU and wanted to be seen as reliable partners who do not fail their obligations. The transmission grid was privatized quickly in both countries. The Czech part was bought by a consortium of German Ruhrgas, Gaz de France, and Russian Gazprom, whereas the Slovakian part went to the German RWE. The Ukraine, in contrast, was not a candidate for membership in the EU. On the other hand, political ties with Russia became weaker, so that the Ukraine resulted as the only truly independent transit country for Russian gas.

Russia paid a transit fee in form of gas to Ukraine while continuing to offer cheap gas for the country's own use. Problems arose when Ukraine started leaving its gas bills unpaid and further on was accused by Russia of stealing gas that was meant for export to Western Europe.

Russia and the EU had strong concerns about the reliability of Ukraine and looked for alternative transit routes. The northern corridor through Belarus and Poland to Germany seemed to be the solution. Belarus was politically much closer to Russia than the Ukraine. Poland turned out to be no obstacle for transit since it was seeking integration with the EU, like Slovakia and the Czech Republic. Additionally, Gazprom managed to obtain heavy influence in the Polish transit grid EuroPolGaz, by holding an amount of shares equal to that of the Polish PGNiG. This paved the way for building the massive Yamal-Europe pipeline using that route. Originally it should transport gas from the giant Yamal field, but developing costs turned out to be too high for the time being. The project was continuously scaled down and finally in 1999, one pipeline with a maximum capacity of 28 bcm/a (billion cubic meters per year) was finally constructed. However, only compressors for 18 bcm/a have been installed so far (Hubert & Ikonnikova, 2004). This pipeline will be referred as Yamal 1 in the following. The Yamal project contains options to build a second and third parallel pipeline, Yamal 2 and 3, to achieve a total capacity of 56 bcm/a and 84 bcm/a, respectively (Hirschhausen v., 2003). The cost of Yamal 1 amounted to \$3.4 billion, whereas the construction cost for Yamal 2 and 3 are estimated at \$2.5 billion each.

Increasing frustration with the transit countries led Russia to develop direct export routes. The first to be realized was the Blue Stream pipeline from Russia through the Black Sea to Turkey. Thus, Ukraine lost its transit monopoly on the route to Southeast Europe, where the old pipeline runs from Russia through the Ukraine, Moldova, Romania, and Bulgaria to Turkey. Transmission through Blue Stream started in 2003 with 2 bcm/a and will increase steadily until 2010 when the full capacity of 16 bcm/a will be reached (Gazprom, 2006). The

possibility of bypassing the Ukraine southwards weakened Ukraine’s position in dealing with Russia.

A direct pipeline between Russia and Germany, through the Baltic Sea, was discussed for a long time, but was not expected to be built due to much cheaper onshore alternatives. However, at the end of 2005 a joint venture between Gazprom (51%), and the German companies BASF (24.5%) and E.ON (24.5%), signed the contract to construct the North European Gas Pipeline (NEGP). Construction works have already started on the Russian shore. The 1600 km long NEGP is planned to consist of two parallel pipelines with a total capacity of 55 bcm/a. The first pipeline, 27.5 bcm/a, is expected to go on stream in 2010. Total costs are estimated around \$5 billion (NEGP, 2006).

Figure 1 shows existing and projected transport routes from Russia to Western Europe.

Figure 1: Western Russian gas export routes



Source: DIW Berlin

## 2.2 Russia

After the collapse of the Soviet Union, Russia was surrounded by newly independent states in the west and south. It continued to control the lion's share of energy resources but was now dependent on transit countries for energy export, especially gas. Russian and Central Asian gas is landlocked and thus has to be transported by pipeline over long distances. The biggest gas fields are along the Ural and in Western Siberia, thousands of kilometers away from Western Europe. Other forms of transport, like LNG, CNG or the conversion of gas into chemical liquids or electricity are not technically mature or not appropriate for Russia's current export situation towards Western Europe. One ton of gas occupies more than thousand times the volume of one ton of oil and is therefore much more difficult and costly to transport (IFP, 2002). Transportation costs usually represent a big part of the overall cost of delivered gas to the end user.

Russian gas production fell during the 1990's due to collapsing domestic demand after the break-up of the Soviet Union, export restrictions, and depletion of the production fields. Recovery has been seen since, mostly thanks to increasing exports, bringing Russian production up to 589 bcm in 2004 (BP, 2005). The production is projected to reach 655 bcm in 2010 and 898 bcm in 2030, which forces Russia to soon develop several new fields to compensate the production decline of three old giant fields and additionally increase total production. Worldwide, Russia's own gas reserves are the largest in a single country. Proven reserves amount to 47 trcm, which represents 26% of the world's total. Russia's neighbors in the Caspian region, mainly Turkmenistan and Kazakhstan, have large reserves, around 8 trcm, that are relatively easy to recover and have barely been exploited after Soviet time. Gazprom has already bought over 1 trcm of this gas under long-term deals. This helps Gazprom to serve growing demand and postpone the development of new expensive Russian fields that are located in difficult terrain. On the other hand, Gazprom ties these countries to the Russian transportation grid since no alternative route exists there yet. This hinders them to export directly to Western Europe, which would make them competitors of Russia (IEA, 2004). Consequently, Russia can keep its market power through foreign gas that it re-exports. An alternative route through the Caspian Sea to Turkey is planned. If Russia learned its lesson from the transit problems with Ukraine and Belarus; it will offer the Caspian producers prices that allow them to make enough profit. This would keep the plans for alternative routes frozen, which is in Russia's interest.

Gazprom is the world's biggest gas company although it is diversifying in other sectors like oil. Gazprom is responsible for over 90% of Russian gas production, owns the national

pipeline grid, and has a monopoly for exports outside the CIS. Energy exports are the most important source of governmental revenue, with Gazprom alone providing around 25% of federal tax revenue. While exports to Western Europe are lucrative, domestic sales and exports to former Soviet states are not very profitable due to regulated or highly subsidized prices and non-payment of customers/importers (Bruce, 2005).

Gazprom was mostly privatized, causing it to pursue interests and goals different from those of the government. With Putin's election, the reintegration of Gazprom began. Governmental share increased and managers loyal to Moscow were installed. This made it easier for the government to implement its energy policy and permitted gas to be used as a political instrument (Bruce, 2005).

Unlike Ukraine and Belarus, Russia during the past decades made great effort to gain a reputation as a reliable supplier of Western Europe. Even in phases of internal turmoil, Russia sought to guarantee the gas flow westwards (Hubert & Ikonnikova, 2003). Recognizing the importance of the transit routes, it strived to achieve control over the gas transit assets in Ukraine and Belarus. Russia used the unpaid gas bills and the threat of supply cuts to put pressure on these countries, trying to trade gas debts for influence on the transit system (Bruce, 2005).

Problems with transit countries and the quest for diversification have escalated to a point that Russia is willing to pay a high price to secure its autarky in transport. This means particularly shifting transit routes from risky to safe areas, which could be reliable neighbors or own territory. Another reason is Russia's unwillingness to pay transit fees for services that had been free of charge during Soviet times (Laurila, 2002). First signs to this effect were the completion of the Yamal-Europe and the Blue Stream projects. The latest step was the commitment to the NEGP, which connects Russia directly with Germany through the Baltic Sea, bypassing all transit countries. This is certainly the strongest signal to the transit countries. Gazprom could try to imitate the behavior of major Russian oil companies during the 1990s. They managed to play off the Baltic ports against each other to push down transit fees while increasing oil exports through their own Russian ports (Laurila, 2003). Russia's behavior must be seen in the light of a quest for power, relying on dependencies based on competition, cooperation, and rivalry between neighboring countries.



## 2.2 Ukraine

Until recently, Ukraine had a quasi-monopolistic position in the forwarding of Russian gas to Western Europe, the Balkans, and Turkey. It used this position to influence prices and quantities. The incentive to pursue such a policy clearly exists since transit fees represent about 10% of Ukraine's export revenues. Evidence of monopolistic behavior can be seen in the fact that effective transit fees were much higher than effective marginal cost (Opitz & Hirschhausen v., 2000). The technical state of the pipelines in Ukraine is said to be very poor due to its age and chronic underinvestment, leading to reduced capacity and excessive fuel consumption by compressors, which means higher transport cost.

In the 1990s, more than 95% of the Russian gas to Western Europe passed Ukraine, the rest through low-pressure pipelines in Belarus and Poland. The total transit capacity of Ukrainian pipelines westwards is estimated at 100 bcm/a and southwards at 40 bcm/a. The transit fee is not paid in cash but in gas. Gazprom and Naftogaz negotiate on the gas price and transit fee annually. The official transit price is of no importance; what counts is the amount of gas delivered and its value (Opitz & Hirschhausen v., 2000).

In the time after the Soviet Union, Ukraine was seeking to maintain its newfound sovereignty and independence from Russia. Due to permanent problems with Russia, Ukraine's reputation as a reliable transit country is dire. Different political orientations, decreasing economic interactions, Ukrainian energy debts going into billions of dollars and many other problems caused the relationship between Ukraine and Russia to turn sour (Moshes, 2000).

Despite the many disputes between the two countries, possible cooperation in the gas transmission was discussed. Russia is seeking more influence in the Ukrainian transit pipelines to optimize its cost of transportation. The Ukraine is unable to maintain and upgrade the pipelines on its own; it needs financial help from Russia or Western countries. At the same time, it does not want to give away control over this essential facility which gives the country some power (Tyshchenko, 2002).

Ukraine's proven gas reserves at the end of 2004 amounted to 1.1 tcm, while its own production at that time was 18.3 bcm/a. Its high domestic consumption of over 70 bcm/a shows a clear dependency on gas from Russia (BP, 2005).

In 2004 Russia and Ukraine agreed to increase Ukraine's annual transit capacity by 19 bcm until 2010.

## **2.3 Belarus**

After the collapse of the Soviet Union, Belarus kept strong ties with Russia. Its dictator-like president has no intention to bring his country closer to the EU. The common historical and cultural heritage suggested the idea of reunification, which however was never realized. For Russia, Belarus has primarily been a strategic and military issue, although the control of export routes has become more important. Conversely, for Belarus, Russia is its most important political and economic partner.

Like all the former Soviet republics, Belarus received cheap energy from Russia. The prices for Belarus were even lower than for the others, which helped to boost its economy and made it dependent on Russia. In 2003, Belarus imported 18 bcm of Russian gas at a price of only \$30/tcm, whereas Ukraine paid \$50/tcm and Western importers over \$100/tcm (Bruce, 2005). Belarus has negligible gas reserves of only 20 bcm, which makes it even more dependent than Ukraine on receiving gas from Russia (ENI, 2005).

Although Belarus offers the shortest, and therefore cheapest, way to Western Europe and seemed to be the most reliable transit partner for Russia, problems started to arise shortly after the first gas was pumped through the new Yamal 1 pipeline. Belarus sought to abuse its strategic transit position in an attempt to increase its revenues from transit (Hubert & Ikonnikova, 2005). Moreover, like other transit countries as Ukraine and Moldova, it failed to pay fully for the gas it received from Russia. This undermined its position as a powerful independent transit country. Russia and Gazprom tried to take control over the Belarusian state company Beltransgaz by offering gas debts swaps, but "only" achieved different political and military concessions. Gazprom continues to supply Belarus with cheap gas in exchange for heavily subsidized transit fees (Bruce, 2005).

The result of this continuous up and down in Russo-Belarusian relations is that Belarus is not seen as much more reliable a partner than Ukraine when it comes to gas transport to Western Europe. Therefore it is uncertain whether Russia wants to undertake the construction of the additional Yamal pipelines in near future. The realization of another project, connecting the Yamal pipeline from Belarus through Poland with the southern corridor in Slovakia in order to bypass Ukraine, is even more questionable (Bruce, 2005).

## **2.4 Western Europe**

If not stated otherwise, in the following I will refer to Western Europe as Germany, France, Italy, Austria, Belgium, the Netherlands, the UK, Poland, the Czech Republic, Slovakia and

Hungary as they are currently, will remain, or become the main consumers for Russian gas on routes to the West. These countries together count for more than 88% of the EU's total consumption.

Gas demand is projected to rise in Western Europe in the coming decades, although not as sharply as in the past. The power generation sector will be the main driver of this increase. Natural gas has several environmental advantages compared to other fossil fuels, like lower carbon content and lower damaging emissions. Additionally, capital cost of gas-fired power generators is lower than that of alternative fuels (IEA, 2004).

So far, most gas has been traded under long-term contracts with limited flexibility. Improved interconnections and pertinent EU directives led to an opening of the markets, causing first spot markets for gas to emerge, and average life of new gas contracts to decrease. This development is expected to go on until the gas market is characterized by spot trades and short-term contracts rather than long-term "take-or-pay" contracts that are tied to oil prices (Neumann & Hirschhausen v., 2004). Reform of the gas market in Europe is led by the UK, where the market is already liberalized completely. Other EU countries are expected to follow suit, which will make the market more efficient.

Western Europe's proven gas reserves (excluding Norway) amount to 3.4 trcm, which represents only 2% of the world's total. The two main gas producers in Western Europe are the UK and the Netherlands, who together account for around 75% of total production. However, the UK is predicted to turn into a net importer at the end of this decade already. Some additional production is generated in Germany, Italy, and Poland. Western European production has already reached its peak and will decline sharply after 2010. The Netherlands will then be the only net exporter of Western Europe. The necessary imports will mainly come from the three big suppliers who already today provide most imports, viz. Algeria, Norway, and Russia. Russia is and will remain the biggest single supplier for Western Europe. Although these countries will increase their export volumes shipped to Western Europe, they will not be able to cover the demand for gas on their own. Excess demand is expected to be met mostly by LNG (liquefied natural gas) coming from the Middle East, and Western Africa (IEA, 2004). Table 1 shows the current and expected future situation of Western Europe.

Turkey, and to a smaller extent Greece, also are important importers of Russian gas. They are not included in the definition of Western Europe introduced above because the gas is transported on different pipelines across the Ukraine (see Figure 1). Turkey's reserves are about to be exhausted, and its current production is negligible, which makes it completely

dependent on imports. More than 60% of its gas comes from Russia (BP, 2005). Once pipelines from the Middle East and Caspian region are built, Turkey could become itself a transit country for gas going to Western Europe through Greece and Italy (IEA, 2004).

**Table 1: Western Europe's gas prospects**

<b>Western Europe</b>	<b>2004*</b>	<b>2010**</b>	<b>2030**</b>
<b>Consumption (bcm/a)</b>	413	502	696
<b>Own production (bcm/a)</b>	199	208	136
<b>Total imports (bcm/a)</b>	214	294	560
<b>Imports from Russia (bcm/a)</b>	111	129	150

Sources: \*BP, ENI; \*\*IEA

### 3. Model

Cooperative and non-cooperative game theory are usually seen as two different game theories rather than two types of one game theory, although both have their roots in the work by von Neumann and Morgenstern (1944). Non-cooperative game theory is part of microeconomics, focusing on the players with their actions, strategies, information and payoffs. The Nash - equilibrium represents the most common solution concept. It does not involve co-operation; in the limit of an atomistic market, it coincides with the competitive equilibrium, in which agents on the demand and supply act independently. In contrast, in the present context players are bound together because they share a common resource, viz. a (very simple) network. Moreover, the payoffs are structured in a way that a total lack of cooperation would result in sizable losses for all parties concerned, contrary to the situation typically characterizing non-cooperative game theory. Finally, the question to be answered here is not so much as to what quantities are transacted at what price but which players will cooperate with Russia (who necessarily is included in any coalition, being the only producer of gas of any importance). Cooperative game theory is payoff-orientated. Its advantage is that the exact details regarding strategies, actions etc. need not to be known. Cooperative game theory is founded on the capabilities of players and coalitions, and the results are said to be quite reliable (Wiese, 2005).

The modeling of the gas transit game involves some important assumptions. First, gas is assumed to be a homogeneous commodity, although there are differences in quality, e.g. between Russian and Dutch natural gas. Furthermore, Russia is seen as being in perfect

competition with other suppliers such as Norway, and there are no cartels on the supplier side. This implies Bertrand competition in production. For the transit countries, Russia is the only customer of gas transit services. The market structure is thus a monopoly with very few suppliers of transit service, leading to Cournot competition in the transit game in the case of no cooperation.

The set of players  $N$  consists of Russia, Ukraine and Belarus, to be denoted by  $R$ ,  $U$ , and  $B$  respectively. Governments and respective gas companies will not be distinguished further, since Gazprom, Naftogaz and Beltransgaz are monopolistic, state-owned (or at least state-controlled) companies, causing their decisions and actions to be heavily influenced by the respective government. The total amount of gas transported from the Russian border to Western Europe is denoted by  $x_T$ , no matter where it comes from. The quantities transported through Ukraine, Belarus and the NEGP are indicated as  $x_U$ ,  $x_B$  and  $x_N$  respectively, such that  $x_T = x_U + x_B + x_N$ . All pipelines are assumed to be able to transport any amount of gas between zero and their capacity, ignoring any potential restrictions of a technical nature.

Due to the lack of exact data and in the interest of simplicity, a linear demand function is assumed for Russian gas, as used by other authors before (e.g. Hirschhausen v. et al. 2005). Western Europe's import of Russian gas,  $x_T$ , depends not only on the price, but also on the imports from other regions; therefore,  $x_T(p, x_{\text{others}})$ , where  $p$  stands for the average price of imported gas. Consequently, the inverse demand function can be written as  $p = \alpha(x_T + x_{\text{others}}) + \beta$ , with  $\alpha$  and  $\beta$  as exogenous parameters. In order to focus on gas from Russia,  $x_{\text{others}}$  is made exogenous as well. This is done by summarizing demand for gas from suppliers other than Russia in  $b = \alpha x_{\text{others}} + \beta$ . This gives the inverse demand function

$$(1) \quad p = \alpha x_T + b, \quad \text{where } a = \alpha,$$

with  $a < 0$ ,  $b > 0$  and  $\delta x_T / \delta p < 0$ , hence  $\delta p / \delta x_T < 0$  for all  $p \geq 0$ ,  $x_T \geq 0$ . Furthermore, let the constant unit cost of Russian gas production (including transport to the border) be  $c_R$ . The per unit transport cost from the Russian border to Western Europe through Ukraine or Belarus are  $c_U$  and  $c_B$ , respectively. The per-unit cost of production plus transportation via the NEGP to Western Europe is denoted as  $c_N$ . For simplicity, the cost of past and future pipeline construction are taken as sunk and will be neglected. Thus there are no fixed costs associated with the use of pipelines. The estimated future costs of construction are too vague or not available.

The utility functions of players are equal to monetary payoffs, which are monotonically increasing in profit. A higher payoff is always preferred to a lower one; thus, players are assumed to be risk neutral.

### 3.1 Cooperative game theory

In this section only the market power, which can also be interpreted as the players' bargaining power in the transit game and the outcomes of the grand coalition are derived. Shapley values are calculated as in Hubert and Ikonnikova (2003), but with different assumptions and for different years. Additionally, the Banzhaf value is calculated, which is similar to the Shapley value, but more appropriate in this case as explained later. Both values are ex-ante, predicting payoffs before it is known which players will cooperate. Intuitively, the bargaining power of a player should increase with its importance in the gas chain. Put in another way, the uniqueness of a player is a good measure for its bargaining power. Consequently, the contribution each player makes to all the possible coalitions forms the basis of the measures.

The total number of players is denoted by  $n$ , equal to 3 in all cases considered here. Coalitions  $K$  can be formed with  $k \leq n$  players and a payoff  $v(K)$ . Usually, a coalition's payoff also depends on what the excluded players do. This problem is absent here because Russia is an essential player, without whom no payoff can be realized. A coalition of Ukraine and Belarus alone would not form a complete supply chain, since they have no gas production of their own. Therefore, a coalition must include Russia to generate a payoff. The various possibilities to form coalitions are the following:  $K=\{R,U,B\}$ ,  $\{R,U\}$ ,  $\{R,B\}$ ,  $\{U,B\}$  and the case where each player stays alone. The formula for the Shapley value is

$$(2) \quad \phi_i(v) = \sum_{i \in K} \frac{(k-1)!(n-k)!}{n!} [v(K) - v(K \setminus \{i\})], \quad i \in N.$$

This formula says that each player receives the average of its marginal contributions. A player with no contribution to any coalition will receive no payoff. So, the payoff for each player depends only on its role in this game and nothing else. To understand the Shapley value, it can be interpreted as the forming of an ever larger coalition, with one player being added at a time. The marginal contribution then depends on when a player joins the coalition. The Shapley value assumes that players join randomly, making the probability of every sequence of players the same. The bargaining power  $s$  is then obtained by calculating the relative contribution of a player,

$$(3) \quad s_i = \frac{\phi_i(v)}{\sum_{j=1}^n \phi_j(v)}, \text{ with } \sum_{i=1}^n s_i(v) = 1, i \in N.$$

Tables containing values of  $s_i$  calculated in the present context are presented in section 4.

The Banzhaf value has one major difference to the Shapley value. Rather than assigning equal probabilities to sequences of players, it assigns equal probabilities to all possible coalitions. This seems more realistic as tense political relations between all players do not favor any specific coalition. The formula for the Banzhaf value is accordingly,

$$(4) \quad \beta_i(v) = \frac{1}{2^{n-1}} \sum_{i \in K} [v(K) - v(K \setminus \{i\})], i \in N.$$

The bargaining power  $h_i$  can be calculated as in equation (3) by replacing  $\phi(v)$  by  $\beta(v)$ ;

$$(5) \quad h_i = \frac{\beta_i(v)}{\sum \beta_i(v)}.$$

Every coalition tries to maximize its utility by maximizing profits. Thus the maximization problem is

$$(6) \quad \Pi_K = \sum_{i=1}^k (p - c_i)x_i, i \in N.$$

In the case of the comprehensive coalition  $K=\{R,U,B\}$ , this becomes

$$(7) \quad \max \Pi_{R,U,B} = [a(x_U + x_B + x_N) + b - c_R - c_U]x_U + [a(x_U + x_B + x_N) + b - c_R - c_B]x_B \\ + [a(x_U + x_B + x_N) + b - c_N]x_N.$$

All equations have to be maximized by choosing the right quantity of gas under the constraints  $0 \leq x_U \leq C_U$ ,  $0 \leq x_B \leq C_B$ , and  $0 \leq x_N \leq C_N$  where e.g.  $C_U$  stands for the maximum capacity of the Ukrainian transit pipelines.

A coalition with Russia and the Ukraine,  $K=\{R,U\}$ , has the maximization problem

$$(8) \quad \max \Pi_{R,U} = [a(x_U + x_N) + b - c_R - c_U]x_U + [a(x_U + x_N) + b - c_N]x_N.$$

The corresponding formula for  $K=\{R,B\}$  is

$$(9) \quad \max \Pi_{R,B} = [a(x_B + x_N) + b - c_R - c_B]x_B + [a(x_B + x_N) + b - c_N]x_N.$$

Russia is the only player who can establish a complete supply chain on its own in the future (in scenarios 2010 and 2030), and reaping a profit without cooperating. Its profit maximization problem then becomes

$$(10) \quad \max \Pi_R = [ax_N + b - c_N]x_N.$$

The capacity constraints and parameters of the demand functions change over the years, as shown in section 4.

## 3.2 Non-cooperative game theory

In this section, the calculations for all partial coalitions and the non-cooperative case are derived. Here, the game is a superadditive coalition game with side-payments. This means that a coalition generates more profit than the sum of the single players' profits. Since utility is assumed transferable, players can agree on side-payments, which are possible even if there is no direct economic interaction between them.

Every player can choose between two different actions, viz. to cooperate or not to cooperate with the others. Thus, a player may not join a coalition but still participate in the game as an independent player. The players have different choice variables. Russia decides on the quantity of gas it wants to produce and export to Western Europe and on which route. The transit countries decide on the transit fee for the gas transported through their territory. This is the only variable that Ukraine and Belarus control. For simplicity, the transit fee is paid in cash by Russia rather than in gas or any other form. The transit fees  $t_U$  and  $t_B$ , paid to Ukraine and Belarus, are in \$/tcm.

At the beginning of a period, new quantities and transit fees are set. There is perfect information about cost, demand and bargaining power. In the case of Russia and the cost of the transit countries, this assumption is realistic since Russia built these transit pipelines or was heavily involved in their construction. Therefore, Russia can act as a Stackelberg leader who includes the reaction function of the transit countries in its own profit maximization problem. Once the transit fees and gas quantities are set, there is no renegotiation during the current period, and all parties can be forced to fulfill their part of the agreement.

The transit fee is the result of negotiations between Russia and the respective player. In this model, Russia's bargaining power is used to predict the outcome of the negotiation. Every player knows the amount of the transit fee along with the amount of gas shipped even before negotiating.

Ukraine and Belarus, acting as independent, non-cooperative players have analogous maximization problems. For the Ukraine this reads,

$$(11) \quad \max_{t_U} \Pi_U = (t_U - c_U)x_U.$$

The FOC then is

$$(12) \quad x_U + (t_U - c_U) \frac{\partial x_U}{\partial t_U} = 0,$$

because the amount of  $x_U$  depends on  $t_U$ . In the following  $\sigma := \partial x_U / \partial t_U < 0$ , with  $\sigma$  interpretable as Russia's bargaining power since it shows how much Ukraine's transit fee



setting influences Russia's decision on the gas quantity. Using this, the response functions of Ukraine and Belarus are

$$(13) \quad t_U^* = c_U - \frac{x_U}{\sigma} \quad \text{and}$$

$$(14) \quad t_B^* = c_B - \frac{x_B}{\sigma}.$$

The different periods here are again 2004, 2010 and 2030. The different constellations of players are (R/U/B), ( $\{R,U\}/B$ ), ( $\{R,B\}/U$ ) and (R/ $\{U,B\}$ ), with '/' denoting exclusion. The solution of the big coalition ( $\{R,B,U\}$ ) is shown in section 3.1.

When deciding about the amount of gas to be produced, Russia will look at the marginal cost of transit using the different routes,  $MC_U$ ,  $MC_B$  and  $MC_N$ .  $MC_N$  is constant, given by  $MC_N = c_N - c_R$ .  $MC_U$  and  $MC_B$  vary with  $x_U$  and  $x_B$ , unless Ukraine or Belarus is in a coalition with Russia and gets a constant transit fee. The data from section 4 show that Belarus has the lowest MC for a small  $x$ , while however strongly increasing. Thus, Russia will first use the pipelines through Belarus until  $MC_B = MC_U$ , then those of Belarus and Ukraine jointly, keeping the marginal costs equal, until  $MC_U = MC_B = MC_N$ . At that point, Russia will use the NEGP up to its limit because of its constant marginal cost. If after that, there should still be unmet demand, Russia will distribute the remaining amount between Ukraine and Belarus, again keeping  $MC_U = MC_B$ . Quite generally, the marginal cost of transportation must be the same across routes (always respecting the capacity constraints) in order to maximize Russia's profit. When the capacity constraint of a route is reached, the remaining demand will be transported via the pipeline(s) with free capacity. When its capacity limit is reached, a route can have a marginal cost that differs from that of routes with unused capacity. The equality of marginal cost  $MC_U = MC_B$  implies

$$(15) \quad c_U - \frac{2x_U}{\sigma} = c_B - \frac{2x_B}{\sigma}, \quad \text{implying}$$

$$(16) \quad x_U = \frac{(c_U - c_B)\sigma + 2x_B}{2}, \quad \text{or alternatively, } x_B = \frac{(c_B - c_U)\sigma + 2x_U}{2}.$$

In the case where the players do not cooperate, (R/U/B), the profit maximization problem for Russia is

$$(17) \quad \max \Pi_R = [a(x_U + x_B + x_N) + b - c_R - t_U]x_U + [a(x_U + x_B + x_N) + b - c_R - t_B]x_B \\ + [a(x_U + x_B + x_N) + b - c_N]x_N$$

under the known constraint of non-negative amounts for any  $x$ . Taking the FOCs of (17) by using (13) and (14), and solve them with respect to  $x_U$ ,  $x_B$  and  $x_N$  gives

$$(18) \quad x_U = \frac{c_R + c_U - b - 2ax_B - 2ax_N}{2a + 2/\sigma};$$

$$(19) \quad x_B = \frac{c_R + c_B - b - 2ax_U - 2ax_N}{2a + 2/\sigma}, \quad \text{and}$$

$$(20) \quad x_N = \frac{c_N - b - 2ax_U - 2ax_B}{2a}.$$

Applying the rules formulated above specifying how Russia will fill the different routes and using the formulas (16) to (20), the results can be calculated.

In the scenario ( $\{R,U\}/B$ ),  $MC_U = c_U = 5.14$  is constant, since Ukraine does not charge a profit-making transit fee, being in the coalition with Russia. At the end of the period, Russia will give a certain share of its profits, which is not determined here yet, to Ukraine. Thus, Russia's profit maximization problem is,

$$(21) \quad \max \Pi_{R,U} = [a(x_U + x_B + x_N) + b - c_R - c_U]x_U + [a(x_U + x_B + x_N) + b - c_R - t_B]x_B \\ + [a(x_U + x_B + x_N) + b - c_N]x_N$$

The way of calculation remains the same as before. From the point where  $MC_B = MC_U = 5.14$  is reached, only Ukraine's pipelines will be used up to their limits, benefiting of their constant marginal cost. The FOCs of (21) yield the same values for  $x_B$  and  $x_N$  as in (19) and (20). The difference is in the formula for Ukraine's transit amount,

$$(22) \quad x_U = \frac{c_R + c_U - b - 2ax_B - 2ax_N}{2a}.$$

These results can be calculated using (16), (19), (20), and (22).

In the case ( $\{R,B\}/U$ ), Belarus will charge Russia a transit fee  $t_B = c_B$ , which results in a constant  $MC_B$ . The problem for Russia then looks similar as before,

$$(23) \quad \max \Pi_{R,B} = [a(x_U + x_B + x_N) + b - c_R - t_U]x_U + [a(x_U + x_B + x_N) + b - c_R - c_B]x_B \\ + [a(x_U + x_B + x_N) + b - c_N]x_N.$$

The transit capacity of Belarus will always be used up to its limit first because its marginal cost is lowest. Residual demand is met through the Ukraine and NEGP, as mentioned above. The FOCs of (23) result in (18) and (20) for  $x_U$  and  $x_N$ . In addition to this, one has

$$(24) \quad x_B = \frac{c_R + c_B - b - 2ax_U - 2ax_N}{2a}.$$

These results can be calculated by using (16), (18), (20) and (24).

Finally, if the two transit countries form a transit coalition,  $(R/\{U,B\})$ , they charge a uniform transit fee,  $t_{UB}$  to Russia. In turn, Russia will decide on its own about the total amount of transit gas through these countries,  $x_{UB} = x_U + x_B$ , and the amount of gas through its own NEGP. The transit countries then will divide up the amount of gas to flow through their pipelines. Knowing the marginal cost, it is clear that they will use Belarus' pipelines first. The transit coalition's maximization problem then is

$$(25) \quad \max \Pi_{U,B} = (t_{UB} - c_U)x_U + (t_{UB} - c_B)x_B.$$

By taking the FOC as before and solve for  $t_{UB}$ , one obtains the new reaction function

$$(26) \quad t_{UB} = \frac{(c_U + c_B)\sigma - x_{UB}}{2\sigma}.$$

Russia's maximization problem then becomes

$$(27) \quad \max \Pi_R = [a(x_{UB} + x_N) + b - c_R - t_{UB}]x_{UB} + [a(x_{UB} + x_N) + b - c_N]x_N,$$

and the FOCs are (20) for  $x_N$  and

$$(28) \quad x_{UB} = \frac{c_R + (c_U + c_B)/2 - b - 2ax_N}{2a + 1/\sigma}$$

for  $x_{UB}$ . Use of the different pipelines follows the same logic as above. Russia will first exhaust the capacity of the transit countries to the point where  $MC_{UB} = MC_N$ , and then turn to its own capacity. The results can be calculated by using (16), (20), and (28).

## 4. Data and Results

It is very difficult to obtain consistent and reliable data. Most figures, such as marginal transport cost and the demand function are based on estimations. Even easily measured quantities such as transit capacities or volumes shipped do not seem to be known exactly in view of the wide range of figures published by analysts as well as the pertinent companies and institutions themselves. The rule pursued in this situation was to retain the maximum value.

Maximum effective pipeline capacities are presented in Table 2. In the row "Ukraine", all pipelines through the Ukraine towards Western Europe are included. The data are the official

figures published by Naftogaz. At the moment, no new connection through the Ukraine towards Western Europe is planned. On one hand, Ukraine does not seem to have the necessary financial means to build additional pipelines and on the other hand, foreign investors lack the certainty to invest there. The increase in capacity between 2004 and 2030 exclusively comes from upgrades i.e. replacing old compressors by new ones.

The row “Belarus” contains the Yamal 1 pipeline (which currently runs at 18 bcm/a) and low-pressure pipelines whose capacity are estimated at a constant 2 bcm/a. The completion of Yamal 1 with 28 bcm/a can be expected by 2010 resulting in a total transit capacity of 30 bcm/a. Depending on the development of relationships with Russia, other transport routes, and Western demand, Yamal 2 and 3 could be accomplished by 2030. At least Yamal 2 is likely to be constructed by 2030 because Belarus seeks to increase revenue from transit fees. Yamal 3 is also possible, provided foreign investors can be found. Both variants are entered in table.

**Table 2: Maximum westbound transit capacities in bcm/a**

<b>Pipelines</b>	<b>2004</b>	<b>2010</b>	<b>2030</b>
<b>Ukraine</b>	100	120	120
<b>Belarus</b>	20	30	58/86
<b>NEGP</b>	-	27.5	55

Sources: Hirschhausen v. et al. (2005), Opitz & Hirschhausen v. (2000), NEGP (2006), Hubert & Ikonnikova (2005), Naftogaz (2006)

The NEGP will start in 2010 with a first pipeline. The second one can be expected to be ready by 2030. Russia seeks to strengthen its bargaining power in its relationship with the transit countries by increasing its own capacity. In addition, building a second pipeline usually is cheaper than the first.

Marginal production and transport costs are taken as constant over time in real terms. Development of new gas fields in difficult terrain could increase them; however, in the past technical progress helped reduce cost significantly. Estimations are based on the report of OME (2002), which takes future developments into account. The parameters of the demand function and the cost are taken directly from Hirschhausen v. et al. (2005) which is also based on the OME report, or if not available there, calculated in the same way. The cost estimates are:  $c_R = 12.3$  \$/tcm,  $c_U = 5.14$  \$/tcm,  $c_B = 4.77$  \$/tcm, and  $c_N = 18.54$  \$/tcm. Transporting gas through the NEGP is the most costly variant because most of it is under water, making the use of specialized equipment necessary. The cost through Ukraine are estimated higher than those

of Belarus because the route through Ukraine is longer, the grid is older and in worse condition than through Belarus.

The demand function shifts outward over time, reflecting the fact that total demand is expected to increase further while Western Europe's own production will decline after the depletion of UK reserves (expected around 2010). The constant parameter over the years is  $a = -0.789$ . The outward shifting effect is created by an increasing  $b$ . The estimations are:  $b = 141.1$  \$/tcm for 2004,  $b = 220$  \$/tcm for 2010, which corresponds to the case of "demand expansion" in Hirschhausen v. et al. (2005), and  $b = 260$  \$/tcm for 2030, in keeping with a further increase in demand for Russian gas.

All results presented are rounded and may not match perfectly when used for recalculations.

## 4.1 Results from cooperative game theory

### 4.1.1 Results for 2004

To get the results for the comprehensive / grand coalition, equation (7) has to be maximized. This can be done by using the Kuhn-Tucker conditions or in a simple, intuitive way. Since the marginal cost for the transport through Belarus is lower, the way through Ukraine will not be used unless Belarus reached its capacity. Therefore, first step is to take the FOC of (6) in respect to  $x_B$  (assuming  $x_U = 0$  for now), which gives

$$(29) \quad \frac{\partial \Pi_{R,U,B}}{\partial x_B} = 2ax_B + b - c_R - c_B = 0, \text{ or}$$

$$(30) \quad x_B^* = \frac{c_R + c_B - b}{2a}.$$

When inserting the available data in (30), one sees that the optimal  $x_B$  exceeds the capacity of Belarus. Therefore, the capacity, the capacity constraint  $x_B = C_B = 20$  bcm/a is binding, causing excess demand to be transported through Ukraine. Knowing that, (7) can be differentiated with respect to  $x_U$  to calculate  $x_U^*$ :

$$(31) \quad \frac{\partial \Pi_{R,U,B}}{\partial x_U} = 2ax_U + 2ax_B + b - c_R - c_U = 0, \quad \text{or}$$

$$(32) \quad x_U^* = \frac{c_R + c_U - b - 2ax_B}{2a}$$

Using the data to calculate (1),(7),(30), and (32), one obtains  $x_B^* = 20$  bcm/a (capacity limit),  $x_U^* = 58.365$  bcm/a,  $x_T^* = 78.365$  bcm/a,  $p^* = 79.27$  \$/tcm, and  $\Pi_{R,U,B}^* = 4,853$  M\$.

To calculate the results for  $K=\{R,U\}$ , the derivative of (8) has to be taken w.r.t.  $x_U$ ,

$$(33) \quad \frac{\partial \Pi_{R,U}}{\partial x_U} = 2ax_U + b - c_R - c_U = 0, \quad \text{or}$$

$$(34) \quad x_U^{**} = \frac{c_R + c_U - b}{2a}$$

The results this time are,  $x_U^{**} = 78.365$  bcm/a,  $p^{**} = 79.27$  \$/tcm, and  $\Pi_{R,U}^{**} = 4,845$  M\$.

Finally, the corresponding equations for  $K=\{R,B\}$  are

$$(35) \quad \frac{\partial \Pi_{R,B}}{\partial x_B} = 2ax_B + b - c_R - c_B = 0, \quad \text{or}$$

$$(36) \quad x_B^{***} = \frac{c_R + c_B - b}{2a}.$$

In this case, the capacity limit is reached again so that  $x_B^{***} = 20$  bcm/a,  $p^{***} = 125.32$  \$/tcm, and  $\Pi_{R,B}^{***} = 2,165$  M\$.

To calculate the Shapley value and the Banzhaf value, table 3 showing the marginal contributions is useful. MB stands for the marginal contribution of a player to a coalition in a certain sequence  $\rho$ ; its value depends on the player's position in the sequence. The bargaining power is calculated as from (2), and (3), or (4), and (5), respectively.

**Table 3: Marginal contributions, Shapley value and Banzhaf value 2004**

Sequence $\rho$	$MB_R^\rho$	$MB_U^\rho$	$MB_B^\rho$	Sum
<b>(R, U, B)</b>	0	4,845	8	4,853
<b>(R, B, U)</b>	0	2,688	2,165	4,853
<b>(U, R, B)</b>	4,845	0	8	4,853
<b>(U, B, R)</b>	4,853	0	0	4,853
<b>(B, R, U)</b>	2,165	2,688	0	4,853
<b>(B, U, R)</b>	4,853	0	0	4,853
<b>Sum</b> (=Shapley value, if multiplied by $(1/n!)$ )	16,716	10,221	2,181	29,118
<b>Bargaining power</b> (based on Shapley value)	0.574	0.351	0.075	1
<b>Bargaining power</b> (based on Banzhaf value)	0.561	0.341	0.098	1

### 4.1.2 Results for 2010

Since the NEGP should be operational by 2010, Russia will have transport route under its exclusive control. At the same time, the transit countries are predicted to increase their capacities, as shown in table 2.

As always, the cheapest alternative will be used up to its limit before using the next one in the order of merit. Thus, for  $K=\{R,U,B\}$ , Belarus will be used, followed by Ukraine and, given demand, by the NEGP. Using (30) and (32) and plugging in the numbers, one can see that the capacity of Belarus is fully used. However, Ukraine's capacity limit is not reached, leaving no gas flows through the NEGP. The results are:  $x_B^* = 30$  bcm/a,  $x_U^* = 98.37$  bcm/a,  $x_N^* = 0$  bcm/a,  $p^* = 118.72$  \$/tcm, and  $\Pi_{R,U,B}^* = 13,012$  M\$.

In the case  $K=\{R,U\}$ , Ukraine's capacity will be used before Russia's own. Putting the relevant numbers into (34) shows that Ukraine's capacity is not sufficient to satisfy total demand. Therefore, excess has to be transported through the NEGP. It is calculated as follows

$$(37) \quad \frac{\partial \Pi_{R,U}}{\partial x_N} = 2ax_N + b - c_N + 2a x_U = 0, \quad \text{or}$$

$$(38) \quad x_N^{**} = \frac{c_N - b - 2ax_U}{2a}.$$

In all, the results are  $x_U^{**} = 120$  bcm/a,  $x_N^{**} = 7.67$  bcm/a,  $p^{**} = 119.27$  \$/tcm, and  $\Pi_{R,U}^{**} = 12,992$  M\$.

The outcome for  $K=\{R,B\}$  is calculated in analogous manner. It turns out that the capacity of Belarus will not be enough to supply the amount of gas demanded. To calculate how much will be pumped through the NEGP, the pertinent FOC is used,

$$(39) \quad \frac{\partial \Pi_{R,B}}{\partial x_N} = 2ax_N + b - c_N + 2a x_B = 0, \quad \text{or}$$

$$(40) \quad x_N^{***} = \frac{c_N - b - 2ax_B}{2a}.$$

The results show that the NEGP capacity limit would be exceeded too, hence  $x_B^{***} = 30$  bcm/a,  $x_N^{***} = 27.5$  bcm/a,  $p^{***} = 174.63$  \$/tcm, and  $\Pi_{R,B}^{***} = 9,019$  M\$.

For Russia alone, differentiating (10) yields,

$$(41) \quad \frac{\partial \Pi_R}{\partial x_N} = 2ax_N + b - c_N = 0, \quad \text{or}$$

$$(42) \quad x_N^{\circ} = \frac{c_N - b}{2a}.$$

The outcomes are therefore  $x_N^\circ = 27.5$  bcm/a,  $p^\circ = 198.3$  \$/tcm, and  $\Pi_R^\circ = 4,943$  M\$, taking account of the capacity constraint. The bargaining powers can be calculated with the formula or with a table as before. The results for 2010 are presented in table 4.

**Table 4: Bargaining power (2010)**

	<b>Russia</b>	<b>Ukraine</b>	<b>Belarus</b>	<b>Sum</b>
<b>Bargaining power</b> (based on Shapley value)	0.742	0.205	0.053	1
<b>Bargaining power</b> (based on Banzhaf value)	0.712	0.215	0.073	1

### 4.1.3 Results for 2030

The calculations are analogous to the ones for the year 2010. Assuming that Belarus completes only the Yamal 2 (Variant no.1), they are,

$K = \{R,U,B\}$ :  $x_B^* = 58$  bcm/a,  $x_U^* = 95.7$  bcm/a,  $x_N^* = 0$  bcm/a,  $p^* = 138.72$  \$/tcm,  $\Pi_{R,U,B}^* = 18,664$  M\$;

$K = \{R,U\}$ :  $x_U^{**} = 120$  bcm/a,  $x_N^{**} = 33.02$  bcm/a,  $p^{**} = 139.27$ ,  $\Pi_{R,U}^{**} = 18,606$  M\$;

$K = \{R,B\}$ :  $x_B^{***} = 58$  bcm/a,  $x_N^{***} = 55$  bcm/a,  $p^{***} = 170.84$  \$/tcm,  $\Pi_{R,B}^{***} = 17,295$  M\$;

$K = \{R\}$ :  $x_N^\circ = 55$  bcm/a,  $p^\circ = 216.6$  \$/tcm,  $\Pi_R^\circ = 10,893$  M\$.

The associated values of bargaining power are displayed in table 5.

**Table 5: Bargaining power (2030, Variant 1)**

	<b>Russia</b>	<b>Ukraine</b>	<b>Belarus</b>	<b>Sum</b>
<b>Bargaining power</b> (based on Shapley value)	0.849	0.093	0.058	1
<b>Bargaining power</b> (based on Banzhaf value)	0.808	0.112	0.080	1

Under assumption that construction of Yamal 3 is achieved by 2030 (Variant no.2), the results look like follows,

$K = \{R,U,B\}$ :  $x_B^* = 86$  bcm/a,  $x_U^* = 67.7$  bcm/a,  $x_N^* = 0$  bcm/a,  $p^* = 138.72$  \$/tcm,  $\Pi_{R,U,B}^* = 18,674$  M\$;

$K = \{R,U\}$ :  $x_U^{**} = 120$  bcm/a,  $x_N^{**} = 33.02$  bcm/a,  $p^{**} = 139.27$ ,  $\Pi_{R,U}^{**} = 18,606$  M\$;



$K = \{R,B\}: x_B^{***} = 86 \text{ bcm/a}, x_N^{***} = 55 \text{ bcm/a}, p^{***} = 148.75 \text{ \$/tcm}, \Pi_{R,B}^{***} = 18,486 \text{ M\$};$

$K = \{R\}: x_N^{\circ} = 55 \text{ bcm/a}, p^{\circ} = 216.6 \text{ \$/tcm}, \Pi_R^{\circ} = 10,893 \text{ M\$}.$

The resulting bargaining powers are entered in table 6.

**Table 6: Bargaining power (2030, Variant2)**

	<b>Russia</b>	<b>Ukraine</b>	<b>Belarus</b>	<b>Sum</b>
<b>Bargaining power</b> (based on Shapley value)	0.859	0.072	0.069	1
<b>Bargaining power</b> (based on Banzhaf value)	0.811	0.096	0.093	1

#### 4.1.4 Interpretation

In 2004, Russia is a veto player, which means that no coalition without it can realize a payoff. This gives Russia a good deal of power in the bargaining process (see table 3). In the later scenarios, Russia becomes even a dictator player. This means that while Russia is still essential to the other players in establishing a supply chain, it now can also generate a certain payoff independently from the others. This results in a higher bargaining power of Russia that increases over time (see tables 4 to 6).

Conversely, Ukraine's bargaining power decreases over time. In 2004, Ukraine provides the lion's share of transit capacities, which makes Russia very dependent on Ukraine's willingness to cooperate. In the later years, Ukraine's competitor Belarus has higher capacity, and Russia has some capacity of its own. At the same time, Ukraine's capacity is increasing only by little, which explains the decline in its bargaining power (see tables 3 to 6 again).

By way of contrast, the bargaining power of Belarus is quite constant over time. This is because of two opposing influences that tend to counterbalance each other. On the one hand, the construction of the NEGP serves to decrease this country's importance; on the other hand, Belarus strengthens its position by increasing its transit capacity distinctively.

Finally, note that the Banzhaf values do not differ much from the Shapley values. They tend to be slightly higher than the Shapley values at the low end and somewhat lower at the high end. The explanation is that assuming equal probability for all possible coalitions rather than for all sequences of players serves to sustain the weak players.

## 4.2 Results from non-cooperative game theory

In this section, all demand and cost parameters remain the same as previously. The problem is to translate Russia's bargaining power ( $bp_R$ , obtained from the Banzhaf value, say) into the indicator of bargaining power ( $\sigma$ ) derived below (12) and appearing in (13) and (14). When  $bp_R \rightarrow 1$ , indicating that Russia has maximum bargaining power, then  $\sigma \rightarrow -\infty$ , while when  $bp_R \rightarrow 0$ , then  $\sigma \rightarrow -1$ . This follows from  $T_i := \partial x_i / \partial t_i$ , which shows how strongly Western gas demand responds to the transit fee imposed by country  $i$ . The non-cooperative scenario can only arise with  $bp_R = ]0,1[$ . If  $bp_R = 0$ , Russia has no bargaining power at all, whereas if  $bp_R = 1$ , it has all the bargaining power. In the first case, it is constrained to cooperate, while in the second case, it can force the others to cooperate. An intermediate value is available from Hirschhausen v. et al. (2005), who calibrates  $\sigma$  to  $-8.13953$  for a year where  $bp_R = 0.5$ , and the Ukraine is the only transit country. With this information, I estimated the following function to transform Russia's bargaining power from  $bp_R$  into  $\sigma_R$ :

$$(43) \quad \sigma_R = \frac{16.56298716^{bp_R}}{1 - bp_R} (-1).$$

### 4.2.1 Results for 2004

Russia's bargaining power for the year 2004 is  $\sigma_R = -11$  according to (43). Moreover,  $x_N = 0$ , since the NEGP did not exist yet. Other parameters and the results for ( $\{R,U,B\}$ ) are taken from the cooperative scenarios derived in section 4.1. For the year 2004,  $MC_B = MC_U = 5.14$  (which is the marginal cost that Ukraine has) is reached at the amount  $x_B = 2.04$ . The respective formulas from section 3.2 are used to calculate the outcomes for the different coalitions. The results are presented in table 7; they are for this period only, hence expressed as quantities per year. The total amount of gas from this simulation is lower than the actual flows measured in 2004. This is because the demand function was estimated for earlier years neglecting the increase in demand that had occurred in the meantime. By shifting the demand function outward, resulting in  $b = 192$ , the simulation results could be made to match actual observations much better. However, the main findings of the simulation are not modified by these changes and therefore  $b$  is left at  $b = 141.1$ .

**Table 7: Results for 2004 (values per year)**

<b>2004</b>	<b>(R/U/B)</b>	<b>({R,U}/B)</b>	<b>({R,B}/U)</b>	<b>(R/{U,B})</b>	<b>({R,U,B})</b>
	<b>(1)</b>	<b>(2)</b>	<b>(3)</b>	<b>(4)</b>	<b>(5)</b>
<b><math>x_U</math> (bcm)</b>	52.33	76.33	52.34	54.21	58.37
<b><math>x_B</math> (bcm)</b>	20	2.04	20	20	20
<b><math>x_N</math> (bcm)</b>	-	-	-	-	-
<b>p (\$/tcm)</b>	84.03	79.27	84.03	82.55	79.27
<b><math>t_U</math> (\$/tcm)</b>	9.9	5.14	9.9	8.33	5.14
<b><math>t_B</math> (\$/tcm)</b>	6.59	4.96	4.77	8.33	4.77
<b><math>\Pi_R</math> (M \$)</b>	4,539			4,595	
<b><math>\Pi_U</math> (M \$)</b>	249		249		
<b><math>\Pi_B</math> (M \$)</b>	36	0.5			
<b><math>\Pi_K</math> (M \$)</b>		4,46	4,575	244	4,853
<b><math>\Sigma \Pi</math></b>	4,824	4,846	4,824	4,839	4,853

As standard economic theory suggests, the largest amount of gas is transported when all players cooperate. Table 7 (last column) confirms this intuition in that both  $x_U$  and  $x_B$  attain their maximum value in this situation. Moreover, the price of gas is minimum ( $p = 79.27$ ). This makes sense, because there is no double-marginalization in a coalition. In the present context, this means that the transit country charges only its marginal transit cost at a first stage. Since it does not try to maximize its profit by setting a transit fee, which allows for a lower end price. Also, the sum of all profits is the highest in the case of the big coalition (4,853 M\$ annually). Thus, the big coalition seems to be the desirable situation for the economy as a whole. Consumers get the most gas for the lowest price, which creates social welfare, while the producer-transporter coalition reaps the highest profit. The opposite situation prevails when every player is on its own and no cooperation is achieved. These findings are true for all years.

For the year 2004, the increase of total profit going from the non-cooperative to the cooperative scenario (involving Russia and Belarus) is very small (see cols. 1 and 3 of table 7). This suggests that this coalition is not very lucrative for either player. In contrast, a coalition consisting of Russia and Ukraine can pay off (see col.2). Provided they can agree on how to divide up the profit, both players are better off.

Surprisingly, the transit countries make a smaller profit when they form a coalition (compare col. 4 with cols. 2 and 5 of table 7). This is a result of the uniform transit fee and Russia's high bargaining power combined with its Stackelberg leader position. A coalition of the transit countries is therefore not predicted for the present (2006).

Entering the payoffs in a matrix as in table 8, one can find the Nash equilibria (NE). The first number always represents the payoff to Russia, the second number, to Ukraine, and the last number, to Belarus. All players can choose between two different actions. They can cooperate with other cooperative player(s), or not cooperate. The base scenario is where all players choose to be non-cooperative. Whenever Russia is part of a coalition, it is assumed to get all the profit and to pay shares  $S_i$  to its coalition partners. This is realistic in view of Russia's dominant position. Profit sharing should be an incentive for the transit countries to form a coalition with Russia. The size of the shares depends on a player's outside option (associated with not cooperating), which varies with the constellation. Every offer  $S_i$  that is higher than a player's outside option will be accepted and cooperation achieved.

Where the coalition consists only of the transit countries, Ukraine is assumed to receive the whole profit and to cede a share to Belarus. It could also be the other way round without affecting the final outcome.

**Table 8: Payoff matrix and Nash equilibria for 2004**

Russia cooperative		Belarus	
		cooperative (c)	not cooperative (nc)
Ukraine	cooperative (c)	<u>4,853</u> - $S_U$ - $S_{B1}$ ; <u><math>S_U</math></u> ; <u><math>S_{B1}</math></u>	<u>4,846</u> - $S_U$ ; <u><math>S_U</math></u> ; 0.5
	not cooperative (nc)	4,575- $S_{B2}$ ; 249 ; <u><math>S_{B2}</math></u>	<u>4,539</u> ; 249 ; 36
Russia not cooperative		Belarus	
		cooperative (c)	not cooperative (nc)
Ukraine	cooperative (c)	4,595 ; 244- $S_{B2}$ ; <u><math>S_{B2}</math></u>	4,539 ; <u>249</u> ; 36
	not cooperative (nc)	<u>4,539</u> ; <u>249</u> ; <u>36</u>	<u>4,539</u> ; <u>249</u> ; <u>36</u>

The underlined payoffs represent the player's best response to the other players' choice. When all three payoffs in a box are underlined, then this box represents a NE in pure strategies, since no player can benefit by changing its action (or their probability weights), given the actions of the others. The same outcome would result when finding the Nash bargaining

solution by maximizing the Nash product. For 2004, the game contains three NE. Russia and Ukraine would prefer the NE with (c,c,c), because they would get a higher payoff than in the non-cooperative scenario, whereas Belarus would be better off in the non-cooperative NE. If there is only one player ready to cooperate, the payoffs are those pertaining to the non-cooperative scenario, since no multi-player coalition can be established.

One could think that Russia, being an essential player with the dominating power, can establish the cooperative NE by offering  $S_U > 249$  and  $S_{B1} > 0.5$ . But Belarus then could try to establish the non-cooperative NE by offering Ukraine a share of its own profit, inducing it to be non-cooperative. However, Belarus could offer a maximum payment of a mere  $35.5 = 36 - 0.5$  to Ukraine, without being worse off itself, while Russia could offer Ukraine up to  $64.5 = 4853 - 249 - 0.5 - 4539$  for cooperation, thus always outbidding Belarus. Therefore the cooperative NE is far more likely to obtain than the non-cooperative NE. Still, the fact that Belarus prefers the non-cooperative NE results in a higher effective payment to Ukraine. Russia has to offer  $S_U > 284.5 = 249 + 35.5$  to make sure that Ukraine will cooperate and not be forestalled by an offer from Belarus. Therefore, Russia's payments sufficient for establishing the grand coalition are  $S_U = 284.5 + \omega$  and  $S_{B1} = 0.5 + \omega$ , with  $S_U + S_{B1} < 314 = 4853 - 4539$  to make sure that Russia is better off as well, and  $\omega > 0$  any small number.

The scenario where all players do not cooperate is always a NE, although it has the lowest sum of payoffs. The reason for that lies in the nature of coalitions. If a single player changes its behavior from non-cooperative to cooperative, it does not change anything in the payoffs because a single-player-coalition is the same as no coalition.

#### 4.2.2 Results for 2010

Russia's bargaining power is calculated as  $\sigma = -25.62$  for the year 2010. Capacities and demand are as presented at the beginning of section 4. The point where  $MC_B = MC_U = 5.14$  is reached is at  $x_B = 4.74$ . The equality of  $MC_B = MC_U = MC_N = 6.24$  occurs at  $x_U = 14.09$  and  $x_B = 18.83$ . The total amount of gas shipped in this simulation (some bcm 128 per year, see top three rows of table 9) squares quite well with the amount predicted by IEA (see section 2.4). It is remarkable that the profits going to Ukraine and Belarus (\$M 178 and 35, respectively) are lower than in 2004 (249 and 36, see table 7, col. 1), although both countries expanded their transit capacities. This can be explained by the increase in Russia's bargaining power through the completion of the NEGP. With its own transport route, Russia changes from an essential player into a dictatorial one. Russia clearly is the big winner, compared to

the last period, with much higher profits, while the transit countries do not really profit from increasing demand. Ukraine's profit decreases in each constellation, whereas the one of Belarus increases a little, except in the non-cooperative constellation.

**Table 9: Results for 2010**

<b>2010</b>	<b>(R/U/B)</b>	<b>({R,U}/B)</b>	<b>({R,B}/U)</b>	<b>(R/{U,B})</b>	<b>({R,U,B})</b>
	<b>(1)</b>	<b>(2)</b>	<b>(3)</b>	<b>(4)</b>	<b>(5)</b>
<b><math>x_U</math> (bcm)</b>	67.52	120	67.52	68.55	98.37
<b><math>x_B</math> (bcm)</b>	30	8.19	30	30	30
<b><math>x_N</math> (bcm)</b>	27.5	0	27.5	27.5	0
<b><math>p</math> (\$/tcm)</b>	121.36	118.85	121.36	120.55	118.72
<b><math>t_U</math> (\$/tcm)</b>	7.78	5.14	7.78	6.88	5.14
<b><math>t_B</math> (\$/tcm)</b>	5.94	5.09	4.77	6.88	4.77
<b><math>\Pi_R</math> (M \$)</b>	12,760			12,795	
<b><math>\Pi_U</math> (M \$)</b>	178		178		
<b><math>\Pi_B</math> (M \$)</b>	35	3			
<b><math>\Pi_K</math> (M \$)</b>		13,001	12,795	182	13,012
<b><math>\Sigma \Pi</math></b>	12,973	13,004	12,973	12,977	13,012

A coalition including Russia and Ukraine again seems to be profitable (cols. 2 and 5 of table 9), whereas a coalition comprising Russia with Belarus is without added benefit. Cooperation between Russia and Ukraine also produces the second-highest total profit, which makes sense because Ukraine is still the provider of most transit capacity, permitting transit gas to be pumped through its pipelines at constant low cost, which results in a higher profit.

Table 10 presents the payoffs for the year 2010. The NE are the same as for 2004. Belarus again prefers the non-cooperative NE and would therefore offer Ukraine a payment up to  $32 = 35 - 3$  for not cooperating with Russia. Thus, Russia's offers to assure the cooperation of the other players are  $S_U > 210$  and  $S_{B1} > 3$ , or  $S_U = 210 + \omega$  and  $S_{B1} = 3 + \omega$ , whereby  $S_U + S_{B1} < 252$ . These payments make sure that the cooperative rather than the non-cooperative NE is achieved.

**Table 10: Payoff matrix and Nash equilibria for 2010**

		Belarus	
		cooperative (c)	not cooperative (nc)
Ukraine	cooperate (c)	$\underline{13,012-S_U-S_{B1}} ; \underline{S_U} ; \underline{S_{B1}}$	$\underline{13,001-S_U} ; \underline{S_U} ; 3$
	not cooperate (nc)	$12,795-S_{B2} ; 178 ; \underline{S_{B2}}$	$\underline{12,760} ; 178 ; 35$
		Belarus	
Russia not cooperative		cooperative (c)	not cooperative (nc)
		cooperative (c)	not cooperative (nc)
Ukraine	cooperative (c)	$12,795 ; 182-S_{B2} ; \underline{S_{B2}}$	$12,760 ; \underline{178} ; 35$
	not cooperative (nc)	$\underline{12,760} ; \underline{178} ; \underline{35}$	$\underline{12,760} ; \underline{178} ; \underline{35}$

### 4.2.3 Results for 2030

As mentioned earlier in section 4, there are two different versions of the scenario 2030. In the first, the capacity limit of Belarus is at 58 bcm/a. Russia's bargaining power is  $\sigma = -50.32$ . The point where  $MC_B = MC_U = 5.14$  is reached is at  $x_B = 9.31$ . The point where the equalities  $MC_B = MC_U = MC_N = 6.24$  are realized is at  $x_U = 27.68$  and  $x_B = 36.99$ . The remaining parameters come from section 4.1.

For the year 2030, the quantity of gas derived from the simulation and the IEA forecast are again quite close. Also, the grand coalition produces the highest total profit and the non-cooperative constellation the lowest. It can clearly be seen that the profit of Russia and Belarus in a coalition exceeds the sum of their non-cooperative profits. Thus, a coalition of Russia and Belarus is beneficial as before. In contrast to the other years however, this profit increment does not approach zero [compare cols. (1) and (3) in tables 9 and 11], because capacity of Belarus has increased, and so have the cost savings of this coalition. It is also remarkable that a transit coalition formed by Ukraine and Belarus now turns profitable [compare cols. (1) and (4) of table 11]. Therefore, if Russia is not cooperative, Ukraine and Belarus can still work together and make themselves better off. This is what standard theory would predict, but this prediction did not materialize in the earlier periods.

Due to the sharp increase in the capacity of Belarus and its lower marginal cost, its profit is higher than that of Ukraine this time. Although Ukraine still has the largest capacity, its profit decreases due to the increase of capacity on cheaper transit routes. Russia's continued increase

in transport capacity results in a higher degree of independency and thus increased bargaining power, which is reflected in its increase in profit.

**Table 11: Results for 2030 (Variant 1)**

2030 (1)	(R/U/B)	({R,U}/B)	({R,B}/U)	(R/{U,B})	({R,U,B})
	(1)	(2)	(3)	(4)	(5)
$x_U$ (bcm)	44.15	120	39.71	39.6	95.7
$x_B$ (bcm)	53.46	33.11	58	58	58
$x_N$ (bcm)	55	0	55	55	0
$p$ (\$/tcm)	139.6	139.19	139.51	139.6	138.72
$t_U$ (\$/tcm)	6.02	5.14	5.93	5.92	5.14
$t_B$ (\$/tcm)	5.83	5.43	4.77	5.92	4.77
$\Pi_R$ (M \$)	18,505			18,504	
$\Pi_U$ (M \$)	39		31		
$\Pi_B$ (M \$)	57	22			
$\Pi_K$ (M \$)		18,633	18,571	98	18,664
$\Sigma \Pi$	18,601	18,654	18,602	18,602	18,664

**Table 12: Payoff matrix and Nash equilibria for 2030 (Variant 1)**

Russia cooperative		Belarus	
		cooperative (c)	not cooperative (nc)
Ukraine	cooperative (c)	$\underline{18,664 - S_{U1} - S_{B1}} ; \underline{S_{U1}} ; \underline{S_{B1}}$	$\underline{18,633 - S_{U2}} ; \underline{S_{U2}} ; 22$
	not cooperative (nc)	$\underline{18,571 - S_{B2}} ; 31 ; \underline{S_{B2}}$	$\underline{18,505} ; 39 ; 57$
Russia not cooperative		Belarus	
		cooperative (c)	not cooperative (nc)
Ukraine	cooperative (c)	$18,504 ; \underline{98 - S_{B2}} ; \underline{S_{B2}}$	$18,505 ; \underline{39} ; 57$
	not cooperative (nc)	$18,505 ; 39 ; \underline{57}$	$\underline{18,505} ; \underline{39} ; \underline{57}$

As Table 12 shows, there are only two NE left, viz. the all cooperative and the all non-cooperative. The third NE disappears because the transit coalition  $K = \{U,B\}$  now turns



profitable and therefore is sought by the players. But against Russia, this coalition fails to be a NE, since Russia prefers the grand coalition. Indeed,  $K = \{R,U,B\}$  gives Russia enough payoff to offer the incentives for Ukraine and Belarus to cooperate. To prevent the transit countries from building a coalition of their own without Russia, it is not sufficient for Russia to offer just the player with the lower profit a higher payment, than it would get in the transit coalition. Since  $S_{B2} > 57$ , Ukraine's maximum profit from a coalition  $K = \{U,B\}$  would be  $98 - S_{B2} < 41$ . Accordingly, Russia seemingly could offer  $S_{U1} \geq 41$  to Ukraine for cooperation, thus undermining this coalition. However, since the omitted player Belarus would only get a payoff of 22, it could make Ukraine a counteroffer  $S_{U3} < 98 - 22$ , that outbids  $S_{U1}$  in order to foster the transit coalition  $K = \{U,B\}$ . The same logic holds in the case where Russia first assures the cooperation of Belarus, causing Ukraine to be left outside. This is also the reason why no coalition with Russia and only one transit country is more profitable than the grand coalition. The outsider would always want to offer the other transit country a payment sufficient to win it over to form a transit coalition. Russia then would have to outbid the outsider to make the partial coalition unattractive. By forming the grand coalition, Russia secures the maximum profit for all players.

The point is that the profitable transit coalition alters the outside options for the participating players. Therefore, the sum of payments that Russia offers to induce cooperation must be more than the payoff of the partial coalition. Specifically, the conditions for achieving the grand coalition are,  $S_{U1} > 39$ ,  $S_{B1} > 57$ , and  $98 < S_{U1} + S_{B1} < 160$ . If Russia were to offer more than 160 in total, then its profit would be higher when not cooperating. Russia may be assumed to distribute its minimum payment as follows. First, it pays each player's minimum requirement. Then, it divides the remainder equally among the members of the coalition. This gives payments of  $S_{U1} > 40 = 39 + 1$  and  $S_{B1} > 58 = 57 + 1$ , or  $S_{U1} = 40 + \omega$  and  $S_{B1} = 58 + \omega$ , with  $\omega > 0$ . Further,  $S_{U2} > 39$  must hold, but this is irrelevant for the existence of a NE.

In the second variant of the scenario 2030, Belarus capacity limit is 86 bcm/a, and Russia's bargaining power is  $\sigma = -51.55$ . The point where  $MC_B = MC_U = 5.14$  is reached is given by  $x_B = 9.54$ . The equality  $MC_B = MC_U = MC_N = 6.24$  holds if  $x_U = 28.35$  and  $x_B = 37.89$ . The other parameters are as before.

Table 13 shows that total profit is maximized when all players cooperate [col. (5)], and it is minimum when they fail to cooperate [col. (1)]. The only difference from the variant no. 1 of 2030 is that Belarus increases its capacity further by completing the third Yamal pipeline.

This leads to an increase in the bargaining power of Russia, who now is in a better position to play out the two transit countries against each other in view of their high spare capacity. In the base scenario [see col. (1) of tables 11 and 13], these players have a slightly lower profit than in variant 1. This implies that it is not profitable for Belarus to construct the third Yamal pipeline by 2030, provided the other assumptions hold true.

**Table 13: Results for 2030 (Variant 2)**

<b>2030 (2)</b>	<b>(R/U/B)</b>	<b>({R,U}/B)</b>	<b>({R,B}/U)</b>	<b>(R/{U,B})</b>	<b>({R,U,B})</b>
	<b>(1)</b>	<b>(2)</b>	<b>(3)</b>	<b>(4)</b>	<b>(5)</b>
$x_U$ (bcm)	44.05	120	28.35	11.63	67.7
$x_B$ (bcm)	53.58	33.13	86	86	86
$x_N$ (bcm)	55	0	38.66	55	0
$p$ (\$/tcm)	139.57	139.18	139.27	139.57	138.72
$t_U$ (\$/tcm)	5.99	5.14	5.63	5.9	5.14
$t_B$ (\$/tcm)	5.81	5.41	4.77	5.9	4.77
$\Pi_R$ (M \$)	18,507			18,506	
$\Pi_U$ (M \$)	38		16		
$\Pi_B$ (M \$)	56	21			
$\Pi_K$ (M \$)		18,633	18,616	106	18,674
$\Sigma \Pi$ (M \$)	18,601	18,654	18,631	18,613	18,674

**Table 14: Payoff matrix and Nash equilibria for 2030 (Variant 2)**

<b>Russia cooperative</b>		<b>Belarus</b>	
		cooperative (c)	not cooperative (nc)
<b>Ukraine</b>	cooperative (c)	$\underline{18,674 - S_{U1} - S_{B1}} ; \underline{S_{U1}} ; \underline{S_{B1}}$	$\underline{18,633 - S_{U2}} ; \underline{S_{U2}} ; 21$
	not cooperative (nc)	$\underline{18,616 - S_{B2}} ; 16 ; \underline{S_{B2}}$	$\underline{18,507} ; 38 ; 56$
<b>Russia not cooperative</b>		<b>Belarus</b>	
		cooperative (c)	not cooperative (nc)
<b>Ukraine</b>	cooperative (c)	$18,506 ; \underline{106 - S_{B2}} ; \underline{S_{B2}}$	$18,507 ; \underline{38} ; 56$
	not cooperative (nc)	$18,507 ; 38 ; \underline{56}$	$\underline{18,507} ; \underline{38} ; \underline{56}$

At first glance, it does not make sense to build an additional pipeline as long as the existing ones are not fully used. However, capacity of Belarus may be fully used in the grand coalition or the transit coalition.

Table 14 shows that the already known NE result here as well. In analogy to variant 1, Russia tries to prevent the transit countries from forming a coalition of their own. To reach this goal, Russia has to offer payments satisfying the following conditions,  $S_{U1} > 38$ ,  $S_{B1} > 56$  and  $106 < S_{U1} + S_{B1} < 168$ . As in variant 1, this implies  $S_{U1} > 44 = 38+6$  and  $S_{B1} > 62 = 56+6$ , or  $S_{U1} = 44+\omega$  and  $S_{B1} = 62+\omega$ . Considering that the game is expected to end up in the grand coalition and comparing the results, one can see that building the third Yamal pipeline is still profitable. although it does not seem so in the non-cooperative constellation.

**4.2.4 Strategy Analysis**

As shown in the preceding subsections, the grand coalition is a NE, constituting only solution for rational players under stated assumptions. It represents a Pareto-efficient solution since no player can increase its payoff without diminishing another player's payoff. Cooperating is thus the dominant strategy for each player in every period provided appropriate incentives are offered. Cooperating is even the dominant strategy when seeing the game as a sequence of repeated interactions over time. This generalization of course is admissible only when the discount rate is zero (or the same) for all players. Different discount rates would affect the bargaining power of the players over time, possibly resulting in different optimal strategies.

Table 15 compares the profits assuming no discounting for each period, using the corresponding values of payments  $S_i$  derived in the previous sections.

**Table 15: Profits for the grand coalition  $K = \{R,U,B\}$**

	<b>Russia</b>	<b>Ukraine</b>	<b>Belarus</b>
<b>2004</b>	4,568 - 2 $\omega$	284.5 + $\omega$	0.5 + $\omega$
<b>2010</b>	12,799 - 2 $\omega$	210 + $\omega$	3 + $\omega$
<b>2030(Variant 1)</b>	18,566 - 2 $\omega$	40 + $\omega$	58 + $\omega$
<b>2030(Variant 2)</b>	18,568 - 2 $\omega$	44 + $\omega$	62 + $\omega$

Russia profits most from an increasing demand for gas. The main reason for its profits being boosted is the availability of an independent transport route through the Baltic Sea. This causes Russia's bargaining power to increase, enabling it to extract a good deal of the transit

countries' profits. As can be seen from table 15, the opening of the first NEGP by 2010 has an enormous effect on Russia's profit. However, the increase in capacity thanks to the second pipeline still brings significant additional payoff. Thus, Russia's strategy of continuously developing and increasing its own transport capacity is very lucrative. Because in the grand coalition, the NEGP is not used at all, the question arises whether its construction is necessary. Yet without this addition to capacity, Russia's bargaining power would be lower. This in turn would require higher payments for establishing the grand coalition, resulting in reduced profits. It is questionable whether if the mere threat of building the NEGP would lead to the same outcomes. Credibility of such a threat may be limited since its realization takes several years. However, construction of the first pipeline probably cannot be stopped anymore. This could be seen as a sufficiently strong commitment to make the threat of adding the second pipeline credible. Russia would not have to build it while still benefiting from an increase of its bargaining power.

Moreover, it is rational for Russia to encourage Belarus to increase its capacity. The logic is that Belarus has the lowest marginal cost of operation, which determines the transit fee charged. This serves to minimize the cost to Russia. Another important factor is that an increase in the capacity of Belarus, weakens Ukraine's situation as the main transit country at least to a certain point. This serves to lower the value of the outside options available to Ukraine, making it less costly for Russia to install the grand coalition.

The situation of Ukraine, in contrast, does not look very bright. Its profits collapse after 2010 due to the emergence of competition between transit routes. Increasing its own capacity cannot change the fact that Belarus has lower marginal cost. Moreover, an increase in that country's capacity, given a profitable transit coalition, does little to increase Ukraine's payoff. The reason is that such an expansion increases profits for the transit coalition and therefore Russia's minimum payment for the grand coalition. Ukraine can benefit from these payments provided Russia allocates them in the way assumed in section 4.2.3 above. This can be seen by going from variant 1 (table 15) to variant 2 as of the year 2030, where payments go up from  $40+\omega$  to  $44+\omega$ . For the Ukraine, the only way to keep a powerful position in the gas chain and to secure high profits is to remain an indispensable partner for Russia. This could have been achieved by preventing Belarus and Russia from developing their transport capacities. It is probably too late for this, since Russia already has started with the construction of the NEGP, while Belarus will not want to forego the opportunity to make money with gas transit. Commitments for cooperation should have been made earlier.

The strategy of Belarus to continuously increase its transit capacity results in increasing payoffs. It is the only way to substantially profit substantial from the gas transit game. Favorable prospects could attract foreign investors to finance the projects. Even Russia is interested in an increase of Belarus' capacity and would presumably act in its favor. Yamal 1 already has been built on Russia's initiative and financial support. On the other hand, Belarus tries hard to maintain control over its transit pipelines to Russia. Any extension of its capacity would mainly cut into Ukraine's profit, adding to existing tension between the two countries.

## **5. Summary and Conclusion**

The emergence of independent transit countries in the Eurasian gas chain has forced Russia to reassess its options. Specifically, Ukraine and Belarus have been trying to capitalize on their strategic transit position by becoming unreliable partners who demand high transit fees, and supplies of cheap gas while failing to pay their gas bills. However, they may have pushed their luck too far, considering their strong economic dependency on Russia. Moreover, the two transit countries cannot expect much EU support in their rift with Russia. First, the EU itself is quite dependent on Russian energy supplies. Second, Belarus is isolated from the EU because of its political system, while the Ukraine is not a candidate for accession to the EU. Russia in turn is reluctant to pay high transit fees to "its former provinces", rather, it seeks to reinstall autarky with regard to gas transports. It tries to foreclose competition by buying the gas from the Caspian region and selling it on Western markets, rather than competing with these countries directly. The construction of direct, independent transport routes to customers such as Blue Stream and NEGP serves this objective. It may also reflect Russia's continuing dissatisfaction with the transit countries.

The building of transport routes under its exclusive control boosts Russia's bargaining power vis-à-vis the too transit countries. Consequently, Russia can siphon off profits and benefit from an increasing demand for gas. Wielding this market power, Russia is capable of establishing the grand coalition (comprising all the three countries considered) at a lower cost. Side payments to the transit countries decrease because their outside options become less valuable. The increase in demand somewhat eases the situation for the transit countries, as the amount of the demanded gas exceeds Russia's own transport capacity, leaving some transit demand even in the worst case. Belarus may see its bargaining power enhanced by expanding its transit capacity. However, this would require investment that would have to come primarily from outside. Finally it is to the advantage of Russia if Belarus becomes a

counterbalancing factor against Ukraine. Accordingly, Russia is predicted to support these projects, which foster competition between transit countries. This will put pressure on transit fees, provided there is sufficient capacity, allowing choice between transit routes. Ukraine, on the other hand, seems to be the big loser. Its bargaining power and profits are predicted to continuously decrease during the next two decades while those of its two neighbors will increase. Increasing capacity is no option for the Ukraine since this would only create more idle capacity without enhancing its position in the gas transit game. Ukraine cannot hinder Russia from building at least the first pipeline of the NEGP (North European Gas Pipeline), and it probably has no chance to convince Belarus to abstain from increasing capacity. The only viable alternative for Ukraine is to remain in its lucrative position, upgrading its pipeline system in order to reduce its marginal cost, thus gaining a competitive edge over Belarus.

In all, the game-theoretic analysis performed in this paper leads to the prediction that Russia will succeed in forging a grand coalition comprising all the three countries studied here. The grand coalition is also the only Pareto-efficient Nash equilibria of the gas transit game, offering maximum payoff to each player, with side payments, sufficient for its creation and maintenance. Even for the consumers in Western Europe, the grand coalition is a favorable outcome because it delivers a maximum amount of gas at the lowest unit price.

The analysis performed in this thesis is purely economic, based on several assumptions, and subject to important limitations. In reality, the gas transit game is riddled by problems not addressed here, ranging from geopolitical to military interests of the participating countries. The gas companies are not independent from the government, and they are often used to achieve political goals. Furthermore, there exist no formal enforcement mechanisms for international contracts. As seen recently, transit countries can breach agreements without having to fear well-defined sanctions. Indeed, breach of contract constitutes a big threat to both sides of any gas transit agreement, at least until construction of the NEGP is completed. Afterwards, the hold-up problem rapidly loses importance for Russia.

Nevertheless, gas flows were never interrupted for a longer period of time. The risk of such an interruption is indeed small. Since Russia has the means to put enormous pressure on the transit countries, who depend on Russia in many ways. An open conflict would harm them far more than Russia.

Nevertheless, the economic analysis performed here is useful to understand the impacts of future changes on the gas chain. Various scenarios can be played through, using published estimates in particular capacity developments, to predict outcomes in terms of prices, quantity

of gas delivered, and profits accruing to companies and respective governments. Not surprisingly, the quality of these predictions crucially depends on the accuracy of the estimates of demand and cost. Finally, bargaining power could be calculated in more dynamic ways, taking into account political circumstances, goals, and sways of each player.

## Abbreviations

<b>B</b>	Belarus
<b>Bcm</b>	Billion cubic meters ( $10^9 \text{ m}^3$ )
<b>Bcm/a</b>	Billion cubic meters per year ( $10^9 \text{ m}^3 / \text{a}$ )
<b><math>c_i</math></b>	Constant marginal cost for player $i$
<b><math>C_i</math></b>	Transport capacity on player $i$ 's route
<b>CIS</b>	Commonwealth of Independent States
<b>CNG</b>	Compressed natural gas
<b>EU</b>	European Union
<b>FOC</b>	First order condition
<b>IEA</b>	International Energy Agency
<b>Km</b>	Kilometer
<b>LNG</b>	Liquefied natural gas
<b>M</b>	Million
<b><math>MB_i^p</math></b>	Marginal contribution of player $i$ in the sequence $p$ (in M\$)
<b><math>MC_i</math></b>	Marginal cost in \$ for Russia to transit 1 tcm of gas through player $i$ 's territory
<b>NE</b>	Nash-equilibrium
<b>NEGP</b>	North European Gas Pipeline
<b>OME</b>	Observatoire Méditerranéen de l'Energie
<b><math>p</math></b>	Price of gas at Western European border in \$/tcm
<b>R</b>	Russia
<b><math>S_i</math></b>	Payment to player $i$ in million \$
<b><math>t_i</math></b>	Transit fee in \$/tcm charged by player $i$
<b>Tcm</b>	Thousand cubic meters
<b>Trcm</b>	Trillion cubic meter ( $10^{12} \text{ m}^3$ )
<b>U</b>	Ukraine
<b>UK</b>	United Kingdom
<b><math>x</math></b>	Amount of gas in bcm through player $i$ 's route
<b>\$</b>	US Dollar



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