Coalition Formation, Bargaining and Investments in Networks with Externalities: Analysis of the Eurasian Gas Supply Network

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Abstract

We present a new methodology to study how upstream (e.g. producers) and downstream (e.g. transiters) players form coalitions, bargain over joint profit sharing and invest. Within coalitions players combine resources, coalitions compete on a market. Profit of each coalition depends on the cooperation among the outside players. Hence, we consider a game with externalities. To find the equilibrium coalition structure and the expected payoffs, we use the solution proposed by Maskin (2003). Payoffs reflect the bargaining power and depend on capacities of players. We show, how investment options available to players matter.

We apply the study to analyze the Eurasian gas supply network. Russia and Turkmenistan - producers and Ukraine, Belorus, Azerbaijan, Iran - transiters form coalitions to supply gas and bargain over profit sharing. Besides, the players invest in pipelines. We derive the bargaining power of the countries from the architecture of the network and calculate the strategic value of the different pipeline projects.

Keywords: Partition Function, Coalitional Bargaining, Coalition Formation, Externalities, Gas Supply

JEL class.: C7, L1, L7, L9

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1 Introduction

In various industries presented by upstream and downstream players, let us refer to them as producers and transiters. Players cooperate, that is form coalitions, to deliver goods to the market. On the market coalitions compete. The outcome profit of every coalition depends on the coalitions formed by the outside players and capacities available to the coalitions. The profits are shared among coalition members according to their contributions. Contribution determine the bargaining power of a player and depends on his capacities. Therefore, players select investment options strategically as to increase the bargaining power and therewith the share in profit.

In this paper we address the three interrelated questions: how do coalitions form, how do players bargain over joint profit sharing and how do they choose investment options? These questions are relevant to a number of industries, such as natural gas, telecommunications, electricity, transport, and water. In this paper we introduce and test the novel methodology to analyze endogenous coalition formation, bargaining in the presence of externalities and strategic investing problems.

Our study was induced by the lack of analytical instrument to analyze and predict the development of the situation in the Eurasian gas supply network. The network formed by the Former Soviet Union Republics, who produce and deliver gas to the European market. The cooperative and investment decisions of the network players are directly affect the European gas market. Natural gas consumption in Europe is growing while the domestic gas production is declining. By 2015 over 65% of the total gas consumption in EU15 will be covered by external producers. Algeria, Norway and African Republics promise to contribute about 55% of the import needs of Europe. The rest of the import demand should be supplied by the Former Soviet Union (FSU) producers. To reach the European border, gas of the FSU producers passes through a number of transit countries. Then, the issues of cooperation between producers and transiters and investments in transport capacities arise.

Currently, Russia is the only exporter of gas from the Former Soviet region. To deliver its gas to Europe Russia uses the network of pipelines running through the territories of Ukraine and Byelorussia. Thus, we say Russia forms a coalition with two transiters - Ukraine and Byelorussia. For long time Russia has considered investment projects to increase the transport capacities of these countries. That would be the cheapest and fastest possibility to increase supply capacities. Yet, very recently Russia has started building a new pipeline through the Baltic sea, the most expensive of all the investment options. The new pipeline will enable Russia to deliver its gas directly to European borders, bypassing both transiters. Since the collapse of the Soviet Union, Russia has experienced problems negotiating contracts with its transiters. The Baltic pipeline is designed to strengthen Russia's bargaining position with Ukraine and Byelorussia.

Other FSU Republics, namely the Caspian Republics, intend to enter the European market. At present all Caspian export pipelines run through Russia. Thus, the cooperation with Russia is crucial. Yet, the Caspian producers experience difficulties in negotiations of transit contracts. To avoid additional competition, Russia blocks the access to the European market. Recently the European Union and the USA have encouraged Caspian producers to bypass Russia. Trans-Caspian pipeline, through Azerbaijan and Georgia, and Nabucco pipeline via Iran have been designed to bring the Caspian gas to Europe. The pipelines require huge investment capital, but still are waiting for realization. Despite the costs, the pipeline projects will strengthen the bargaining power of the Caspian producers vis-a-vis Russia and raise the profits.

Our analysis is aimed to understand the rational behind the developments in the Eurasian gas network. In particular, we intend to explain the choice of investment options based on the strategic insight. Why producers invest in expensive options and abandon more efficient investment projects? In addition, we find the impact of the network development on the market. We estimate the gas prices and quantities set by the supply coalitions of the Eurasian gas supply network.

We build a framework for our analysis on game theory concepts. We consider, that coalition formation and profit sharing among the players are essentially bargaining situations. Therefore, we use a model of coalitional bargaining to describe the interactions of the network players. Externalities, appeared with possibilities to form competing coalitions, precludes a solution of the bargaining game in a characteristic function form. Thus, we can not apply the solution concepts of Shapley (1953) and Owen (1976).[2] Instead we have to describe the game in so-called the partition function form. A partition function allows to capture the presence of externalities. It assigns the profit to coalitions with respect to the partition, or the coalition structure of players. Several solution concepts has been proposed for partition function form games. The problem of bargaining with externalities can be solved as an extensive form game, e.g. Bloch (1996), Ray, Vohra (1996), Gomes (2001), or with axiomatic approaches, e.g. Do, Norde (2002), Maskin (2003), Ju (2004). In this paper we apply the axiomatic solution proposed by Maskin (2003). In contrast to the other axiomatic approaches, the approach by Maskin (2003) allows simultaneously determine the equilibrium coalition structure and the corresponding payoffs to players.[3] The set of axioms impose desirable properties on the final solution, which make the results tractable.[4]

The number of players in the Eurasian gas network is relatively small. A fair body of data about the future gas demand on the European market enables us to calibrate the demand function. The technology of gas production and pipelines is well known, so that we can estimate production, transportation, and investment costs of gas supply. Thus, we have an opportunity to provide a numerical analysis of the Eurasian gas network. We calculate expected payoffs to the players,

[2]These solutions imply, that a value of a coalition is determined once a coalition is established and is not affected by allocation of outsiders.

[3]In contrast, Do, Norde (2002) and Ju (2004) proposed procedures to calculate expected payoffs of the players. Yet, they assumed the grand coalition including all the players always forms, and thus, neglect the question of a coalition structure.

[4]This fact makes the approach of Maskin (2003) more attractable in comparison against extensive form approaches.

determine the equilibrium coalition structure and investments.[5] Hence, the European gas network provides a rather unique opportunity to confront the theoretical solution of game theory with real world experience. In this respect we can compare how the theoretical predictions correspond to the real behavior of players in the network.

Our quantitative analysis we show how investments affect the balance of bargaining power in the network. In particular, we quantify the importance of different pipelines for the bargaining power of players. Our results confirm the importance of outside options to strengthen the bargaining power. That explains, why Russia has invested into the expensive North European Gas pipeline and why the Caspian producers intend to build the expensive pipelines bypassing Russia. At the same time we reveal, the bargaining advantage of the transiters vis-a-vis the producers if no bypass is possible. The investments in capacities of the transiters do not bring any strategic benefit to the producers, but can only weaken their bargaining position. This fact explains, why Russia postpones its investment in the Upgrade of the Ukrainian transmission system and the Yamal pipeline in Belorus.

The present analysis continues the research of Hubert & Ikonnikova (2003, 2004). They have derived the bargaining power of players of the network endogenously from the architecture of the network and so do we. Yet, Hubert & Ikonnikova (2003, 2004) have considered the network with only one producer. This excludes externality from the consideration and allows to use Shapley (1953) and Owen(1976) concepts to solve the bargaining problem. We extend their work by considering a network, where several competing coalitions may form. Our work also relates to the papers on gas market, e.g. Grais & Zheng (1996), von Hirschhausen & Meinhart & Pavel (2005), and Holz & Kalashnikov (2005). These papers consider the relation between Russia and its transiters and assume, that the producer has all the bargaining power. This again puts aside the issues of competition, externalities and coalition formation.

From a standpoint of a general bargaining problem with externalities, our work relates to studies on other topics. Thus, Eyckmans, Tulkens (2001) explore the issue of Kyoto protocol, where players are countries and externalities are emissions affecting the environment of others. Jehiel, Moldovanu (1996) study a patent acquisition problem, when oligopoly firms collude to buy an innovation from a rival. Fridolfsson, Stennek (2002) analyze preemptive mergers, where firms merge with the hope of avoiding the negative externalities of being an "outsider" of the deal. At last, Calvert, Dietz (1998) consider the formation of political parties. A variety of solution concepts is used to model the problems above and the approach of Maskin (2003) can be applied to any. However, to our knowledge, our work is the first attempt to use the solution of Maskin (2003).

The current paper has a number of issues left for further research. First, we do not explicitly model the interaction of the gas exporters, such as Norway and Algeria, on the European market.

[5]We use data on gas industry and European gas market gathered in Hubert & Ikonnikova (2003).

Rather, we estimate a residual demand for gas from the Former Soviet Union. Second, we assume that the players can credibly commit to the long term agreements. Most of investment cost in capacities are sunk, therefore, the relevant question is, whether the players can commit to long-term cooperation contracts or they are prone to renegotiate their payoffs to extract quasirents. At last, as the data on demand and supply do not allow for a proper econometrical estimation, we stick to linear form of the functions.

The rest of the paper is organized as follows. In the next section we describe the situation in the Eurasian gas supply network and introduce the players and investment options. Therewith we provide a base for the formal model presented in Section 3. Then Section 4 gives quantitative assumptions, which we use further in empirical analysis. The results of our calculations and their interpretation we present in Section 5. Section 6 consists of further discussion and conclusions.

2 Players and options in the network

The Eurasian gas supply network serves to deliver gas produced by the Former Soviet Union Republics to Europe. At present, the network consists of only three players: Russia, Ukraine and Byelorussia.[6] Four other players may join the network in the nearest future. Turkmenistan plans to export its gas to Europe in cooperation with Georgia, Azerbaijan, and Iran.[7] Hereafter we call the countries involved in the gas supply network *players*.

The European gas market is covered by the long-term bilateral "take-or-pay" contracts. These contracts are signed between a producer and a buyer for a period of 15 to 25 years. They fix the price, the buyer is obliged to pay, and the quantities of gas, the producer is obliged to deliver within a contracted period.[8] Thus, contracts allocate the price risk to producers and the volume risk to buyers. The long-term commitments on quantities allow producers to insure heavy up-font investment costs to develop the production and transport infrastructures.

Hence, it is the producers, who have to tackle the transportation issues, including transit relations and coordination of investments in transport capacity.[9] Transiters are often presented by foreign

[6]For the countries considered in our study, the companies engaged in gas trade are state monopolists, therefore we will refer to countries names instead of company names, e.g. Russia instead of Gazprom.

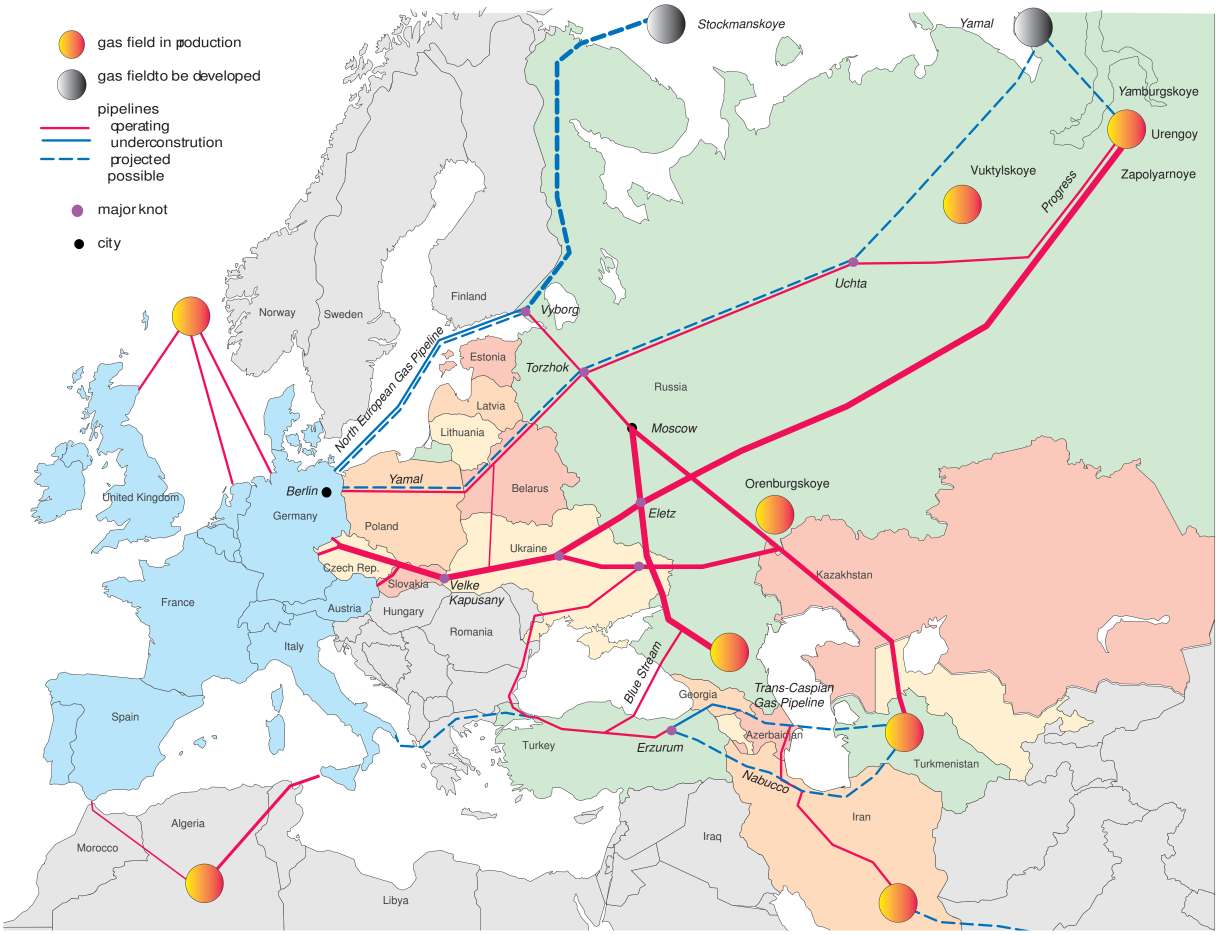
[7]We exclude from the consideration EU transit countries, like Poland, Slovakia, or Czech Republic. Most of the EU members are under the regulation of the Energy Treaty. The agreement obliges its members to grant a third party access to transit pipelines on a fair tariff. For other transit countries, namely Turkey, we assume, that it is on their interest to commit and not to distort transit.

[8]A buyer is obliged to pay for quantities contracted if gas is not taken. On the other hand, producers commit to a limited price change, which may be caused by oil prices rise. Stoppard (1996) and Asch, Osmundsen, Tveteras (2000) discuss "take-or-pay" contracts in more detail.

[9]Although gas buyers often contribute investment capital, they stay away from the supply and transit issues as such. See "Energy Information Administration" on http://www.eia.doe.gov for more information on international

countries. No international court system exist at present to resolve the conflicts among gas supply parties. Therefore, all conflicts concerning transit contracts are resolved through bargaining. At

Figure 1: The Eurasian gas supply network



present only Russia exports gas and signs contracts with Europe. Fields of other Former Soviet Republics, producing gas for export, are connected to export pipelines through the Russian system of pipelines (see Figure 1). Hence, Russia has control over all gas export from the region. After the collapse of the Soviet Union, Russia blocked its potential rivals from the European market. Until now it has enjoyed a monopoly position in the region.

To deliver gas from the Soviet Union to the European market a system of pipelines running through Ukraine, *Ukold*, was built in late 60's. Until the late 90's Ukraine has remained the only transiter of gas to Europe. In the Soviet times decisions upon export quantities, investments in transport capacities and export profit sharing were made and financed centrally. Republics were a single whole, no distinction between transiter and producer existed, and coordination of

pipeline investment projects.

supply was not an issue. Export profits were distributed according a complex system of inner Republics exchange.[10] After the collapse, newly independent countries had to build a new system of relations. Ukraine started bargaining over its share in export profit. Having control over the only transit route, it was in a very strong bargaining position with Russia. Russia had to give up almost a half of its export profits.[11] Yet, Ukraine has demanded for higher transit fees.[12] To fulfill its export obligations Russia would have had to agree on new terms.

To strengthen its bargaining position and gain a leverage on Ukraine, Russia decided to diversify its transit routes. In 1994 Russia started building an alternative pipeline, which should have delivered its gas to Europe bypassing Ukraine. $Yamal1$ pipeline was put into operation in 1998. The pipeline run through Byelorussia and Poland and brought Russian gas to the German border. The pipeline had the capacity of 28bcm/a vs. the Ukrainian 70bcm/a. Yet, the second parallel band, called $Yamal2$, was planned to double the capacity. The project was aimed to weaken the bargaining power of Ukraine and secure the position of Russia. After the dissolution of the Union, the economics of Belorus was in decline and highly dependent on Russian subsidies. Poland intended to join the European Union and developed a reputation of a reliable partner. Therefore Russia relied on the ability of its new transiters to commit. Yet, after the $Yamal1$ started the transmission of gas, Byelorussia initiated renegotiations over a payment for the transit.[13] The strained relations deterred Russia from increase capacity on the Yamal track. Russia again found itself in a vulnerable position.

Meantime, by 2003 Ukraine and Russia reached a tentative agreement. Ukraine agreed to grant Russia control over the transit capacities. Russia promised to attract investments to upgrade and extend the old Ukrainian system. The $Upgrade$ project was aimed to raise the carrying capacity by 15bcm/a, the further extension was to add 35bcm/a more. Until now the $Upgrade$ project remains the cheapest way to increase the capacity of the network. However, Russia has had to turn down the option, after Ukraine has refused to fix Russia's the control rights on a long-term basis.

At last, in 2005 Russia have chosen a project to extend the transit capacity of the network. Of all the alternatives it chose the most expensive project of a North European Gas pipeline, $NEGP$. The pipeline will bring Russian gas through the Baltic sea directly to Germany. Investment costs

[10]Often the pecuniary profit was left in Russia and other Republics were paid in kind for their participation in supply. For history of FSU Republics' relations in the context of gas trade see Stern (1996, 2005).

[11]Russia export over 50bcm/a of gas to Ukraine for internal consumption. Until the year of 2000 Russia set for Ukraine a special low price of about 40$/tcm. That was more than two times less, than the price of gas in Europe. Thus, Russia paid 2.7$/tcm fee in terms of gas for transit of over 100bcm/a to Europe.

[12]Ukraine was unable to pay for the quantities consumed and accumulated a large debt of $1.4bn. In response on nonpayments, Russia reduced its export to Ukraine, but that led to unauthorized syphoning of gas from the export pipeline by Ukraine. To solve its financial problem Ukraine negotiated a higher transit fees ex post.

[13]Similar to Ukraine, Belorus wanted to receive more financial support from Russia, in terms of subsidies, negotiated a higher transit fees ex post.

on this offshore pipeline are twice as high as on any of onshore pipelines, e.g. $Upgrade$ or $Yamal2$. Therefore the option has long been seemed as unviable, but with Russia's failure to reach long-term transit agreements, the NEGP has gained in importance and take on special significance. The outside option to bypass both of the transiters gives Russia a great strategic advantage in bargaining.

The conflict between Russia and its transiters urged other gas producers from the Former Soviet region to seek ways to export their gas to Europe. Besides Russia, a number of Central Asian, i.e. Caspian, Republics possess significant gas reserves and could export over 130bcm/a.[14] The largest producer, Turkmenistan, could supply up to 100bcm/a. In Soviet times Russia added Caspian gas to its export. The milder climate conditions of Caspian fields give an advantage of cheaper production, in comparison with most of Russian fields situated in the permafrost terrain. After 1996 gas demand in Europe fell and to secure its profit Russia squeezed the export of Caspian gas. Russia blocked the access to export pipelines, leaving Caspian producers to sell their gas to neighboring Republics. Gas production of Turkmenistan fell more than twice. Now, the Republic was selling 30bcm/a to Ukraine to meet the demand not covered by gas import from Russia. When Ukraine was unable to pay for import, Turkmenistan simply cut its deliveries. This has put Russia into troubles, as Ukraine has started taking lacking gas from the export pipelines.[15] To relieve itself from the increased burden of import to Ukraine, Russia signed an agreement with Turkmenistan to buy its gas to sell it to Ukraine. Yet, Turkmenistan and other Caspian producers preferred to ensure more stable supply. As the demand in Europe has recovered, Caspian producers has intended to export their gas to the European market.

To reach the European market, Caspian producers have to bypass Russia. Two pipeline projects were proposed to deliver Caspian gas to Turkey, Iran and further to Europe. The Trans-Caspian Pipeline project, TCP, has been design to export Turkmen gas via Turkey and Greece to Italy. The pipeline should run through the two transit countries, i.e. Azerbaijan and Georgia. Another pipeline, $Nabucco$ was planned to pass Iran and again via Turkey enter the European market.

With the independent access to the European market, the Caspian producers will become competitors of Russia. The competition will have a negative effect on Russia's export profits. Hence, the formation of the Caspian gas supply chain will exert negative externalities on Russia's supply chains, that is on Russia's and its transiters payoffs. To mitigate the effect, Russia signed a cooperative agreement with Turkmenistan to increase import of Turkmen gas and thus, to prevent the rival's entry on the market.

As Russia put efforts to turn Caspian gas away from an alternative path, Turkey, European buyers

[14]For comparison in the next decade, given the fields under development, Russia will be able to export from 150 to 180 bcm/a. Further details see Observatoire Mediterraneen de L'Energie (2003).

[15]There are a number of storages of Russian gas on the territory of Ukraine. When the Turkmen export was cut, Ukraine seized the missing gas from the storages.

and United States were pushing the realization of the Nabucco and Trans-Caspian pipelines.[16] The importers consider the pipelines as an instrument to lessen the market power of Russia. The Caspian producers would like to install the pipeline to improve their bargaining position with Russia and achieve higher profits. Every other pipeline strengthens the position of Caspian producers increasing competition among transiters, i.e. Russia, Azerbaijan, Georgia, and Iran.

The options to bypass Russia have already given benefits. In January 2005 Turkmenistan signed a new agreement with Russia, which guarantees the drastic growth of Turkmen gas export from 30 bcm/a to 80 bcm/a. Though the prices are still negotiated, it was agreed, that they will be pegged to the European gas prices. A cooperative supply deal is of particular interest for Russia. Turning Turkmen gas away from Turkish path and directing it through its territory Russia will mitigate negative externalities of the competing link. Moreover, with the help of Turkmen gas Russia will be able to serve its export contracts without developing of the new expensive fields, e.g. Yamal situated in permafrost terrain. Hence, the cooperation enhances the supply efficiency and will confer a higher profit to Russia. The cooperative agreement seems to be a lucrative alternative for Turkmenistan too. Difficulties of cooperation with transiters are to be resolved during the Trans-Caspian and Nabucco project realization. Azerbaijan is in the war with the neighboring Armenia, while Georgia is on the state of the civil war. The conflict between USA and Iran may complicate the financing process of the Nabucco pipeline.

To sum up the information on players, pipelines and investment options for the Eurasian gas supply network see the map on the Figure 1. The existing system of pipelines is marked by the heavy lines. It passes through the territories of Ukraine and Byelorussia and may bring Russian and the Caspian gas to the Western Europe. Therewith we highlight Russia, Turkmenistan, Ukraine and Byelorussia as players. The projects acknowledged as possible options to extend the network drawn by dash lines. Therewith, we add Azerbaijan, Georgia and Iran as players. Recall, the Caspian pipelines allow for gas export bypassing Russia, so we will further refer to two prospective competing coalitions of the network as Russian and Turkmenian, by names of the producers essential for each coalition. Note, that the externalities discussed above is related to the formation of these coalitions, for supply profits depend on the players joining a rival coalition and resources at their disposal.

3 The model

A set of players involved in the network is $N = \{.., i, ..\}$, where $|N| = n$ is the total number of players. For the Eurasian gas network $N = \{r, t, u, b, a, i\}$ consists of Russia, Turkmenistan,

[16]While Europe and USA, are interested in intensifying a competition on the European market, Turkey seeks for gaining profit from reexport or transit. For the history of the project appearance, its motivation, parameters and associated conflicts among the countries involved see Nabiev (2003).

Ukraine, Byelorussia, Azerbaijan, and Iran respectively. The players form coalitions $S_k \subseteq N$. The set of terminal coalitions $P = \{.., S_k, ..\}$ is called a *partition*, or a coalition structure, where $P \in \mathbf{P}$ a set of all possible partitions.[17] We assume coalitions embedded in any partition are pairwise disjoined $S_k \cap S_h = \emptyset$ for all $k \neq h$ and $\bigcup_{k=1}^{|P|} S_k = N$. If all the players play non-cooperatively, the partition is presented by a set of singletons $P = \{.., \{i\}, ..\}$. When all the players cooperate, i.e. form one coalition $P = \{N\}$ we say a grand coalition forms.

Hereafter, we assume, that transfers are allowed within coalitions, but not across coalitions. Members of each coalition play cooperatively and act as to maximize total profit of the coalition, while coalitions play non-cooperatively.[18] Therewith, for every coalition we define a function, which assigns a worth to a coalition given the entire partition:

$$w: \ 2^N \times \mathbf{P} \to R$$
$$(S; P) \mapsto w(S; P)$$

The function is determined on the set of all possible partitions and is called a partition function.

A pair (N, w) presents a game in a partition function form. The outcome of the game is the payoff vector and equilibrium coalition structure (ψ, P). The components of $\psi \in R^n$ are the individual payoffs ψ_i. The game in partition function form allows to capture the presence of externalities and exhibit how the worth of a coalition changes with a coalition structure. Formally speaking externalities are present whenever:

$$\exists S: \ \ w(S; P) \neq w(S; P') \ , \quad \text{for} \quad P \neq P' S_j = \tag{1}$$

there is at least one coalition, which worth changes with the change in a partition. When the inequality sign turns for "greater", the externalities are negative. If the inequality sign is "less", the externalities are positive.

Bargaining and coalition formation To solve the game is to find an equilibrium coalition structure and expected payoffs of the players. We use the axiomatic solution proposed by Maskin (2003). This solution is based on the notion of random order bargaining developed by Weber (1988). The game is conceived as a sequential process. Players enter the game one by one in an order $\theta \in \Theta$, where $\Theta : \ |\Theta| = |N|!$ is a set of all possible permutations of N. Orders of players are assumed equally probably $Pr(\theta) = 1||N|!$. Upon entering a player may join to one of the existing coalitions or start a new one. Depending on allocation of the player is assigned a payoff. When the next player enters, the allocation and the payoffs of all the previous players are known. We consider the game

[17] In general case, the total number of partitions, in which n players may be organized forming k coalition is given by the Stirlings numbers of the second kind S_n^k: $|\mathbf{P}| = \sum_{k=1}^{n} S_n^k = \sum_{k=1}^{n} \frac{1}{k!} \sum_{t=0}^{k} (-1)^{k-t} C_k^t t^n$.

[18] The assumption was first formally introduced by Ray and Vohra (1996) and justified by Bloch (1996), and become a part of a formal description of partition function form games since then.

with complete information, so that profits of coalitions are also common knowledge. The expected payoff of a player and the probability distribution of equilibrium partitions can be obtained as a randomization over θ.

Formally, the approach can be described as follows. A player i enters the game and observes a coalition structure P formed by his predecessors $j: \theta(j) < \theta(i)$. If the player joins coalition $S \in P$ we write $P_{S \cup i}$. If the player sets a new coalition, then $P- > P \cup \{i\} = P_{\{i\}}$. Decisions on allocation are irreversible. For simplicity, we will omit the subscript of the partition on the next step referring to that new partition again as P. Given the allocation, the player obtains a corresponding payoff $\psi_i(P, \theta)$.

The following axioms of Maskin (2003) provide an algorithm to assign players to coalitions and to determine their payoffs:

(i) the sharing of joint profits within every coalition should be Pareto optimal

$$\sum_{i \in S} \psi_i(P, \theta) = w(S; P) \text{ for } \forall i, S \in P \tag{2}$$

(ii) each player is allocated to the coalition S, to which his gross marginal contribution is greatest

$$\begin{gathered} w(S \cup i; P_{S \cup i}) - w(S; P_{S' \cup i}) \geq w(S'' \cup i; P_{S'' \cup i}) - w(S''; P_{S \cup i}) \\ \forall S'' : \quad S'' \neq S \qquad S' = arg \max_{S''}[w(S'' \cup i; P_{S'' \cup i}) - w(S''; P_{S \cup i})] \end{gathered} \tag{3}$$

(iii) every player earns his opportunity wage, or stays with his "stand alone" value

$$\psi_i(P, \theta) = \max[w(S' \cup i; P_{S' \cup i}) - w(S'; P_{S \cup i}),\ w(\{i\}; P_{\{i\}})] \tag{4}$$

(iv) the equilibrium vector of payoffs $\psi^*(\theta)$ and the partition $P^*(\theta)$ should be consistent, that is for the partitions P such that $\forall S \in P\ \exists S' \in P(\theta) : \ S \subseteq S'$ if i is allocated according to (ii), then

$$\psi_i^*(\theta) = \psi_i(P, \theta)$$

In words, the axioms mean the following. The first axiom requires, that coalitions distribute their profits fully among their members. This condition is sometimes called "budget-balancing" and was justified by Aumann and Dreze (1974). The second axiom ensures, that a player gives his resources to a coalition, which benefits from them at most. The axiom also poses the incentives for coalitions to bid for the player. According to (iii) each player gets his highest alternative payoff. Thus, the axiom implies incentives for the player to join the coalition and exposes the value of an outside option. The last axiom refers to sequential rationality and sub-game perfectness, and implies the backward induction.

Altogether the axioms present the algorithm to solve the game. One can determine the vector of payoff and a partition $(\psi^*(\theta), P^*(\theta))$ for all possible orderings $\Theta$and then, calculate the expected payoff vector

$$\psi_i \ = \ \sum_{\theta \in \Theta} \frac{1}{|N|!} \cdot \psi_i^*(\theta) \tag{5}$$

with $1/|N|!$ - the probability of every ordering. Similarly one can draw the probability distribution for the equilibrium partition.

In general, a subgame perfect equilibrium allocation satisfying (ii) may not exist or may not be unique. Yet, for the case of two producers the following proposition is true:

Partition function To solve the game numerically we have to define how the values to partition function are determined. The values of the partition function are defined on the terminal coalition structures. Coalitions are suppliers on the market and play non-cooperatively. We define the worth of a coalition $w(S; P)$ as the maximum profit, the coalition may earn given the actions of the other coalitions on the market. Within a coalition players combine their resources, let k_i is the resources of the player i and $k_S = \sum_{i \in S} k_i$ are the resources of the coalition S. In terms of the gas supply network, resources are the pipelines. Every transiter owns one pipeline, we will denote by $|k_i|$ the capacities along particular pipeline and by $|k_S|$ the total transport capacity of the coalition. We assume, that supply coalitions compete on quantities and define the worth of coalitions by the Cournot-Nash equilibrium:

$$w(S; P) = \max_{q_S} \pi_S(q_{S_1}, .., q_S, .., q_{S_m}) \tag{6}$$

the quantity q_S can not exceed the capacity of the coalition, therefore the coalition may will to invest in capacity over $|k_S|$. How much the coalition will invest and supply depends on the parameters of the profit function, which is expressed as follows:

$$\pi_S = p(q_S)q_S - tc(q_S) - I \cdot (q_S - |k_S|) \tag{7}$$

$p(q)$ is the inverse demand function, $tc(q)$ - total cost of supply, and I denotes the investment capacity costs. We refer to a one shot game, so the expression (7) implies, that the equilibrium capacity of a coalition is equal to the quantity $q_S^* = |k_S^*|$.

Recall, the values of the partition function are calculated for the terminal coalition structure on the market. This will allow us to determine the allocation of the last player and his payoff. To find the allocation and payoffs of the players entering the game earlier we need to know the values of coalitions for intermediate partitions of the players. The values of the partition function for $S_k \in P$: $\cup_k S_k < N$ are redefined as follows:

$$w(S; P) = w(S^T; P^T) - \sum_{i \in S^T \setminus S} \psi_i(P^T, \theta)$$
$$\text{for all } S \in P \text{ and } S^T \in P^T \ : \ S \subseteq S^T$$

here the superscript T means terminal. In words, the value of a coalition S, which is the predecessor of S^T, is the profit of S^T reduced by the payoffs to the players i: $\theta(i) > \theta(j)$ for $j \in S^T \cap S$ and $i \in S^T \setminus S$.

Having the game defined in general terms, we proceed with the quantitative assumptions on $p(q)$, $tc(q)$, and I to solve the game numerically.

4 Quantitative assumptions

Demand The market, we have in mind, is represented by the core members of the European Union – EU15.[19] We refer to these countries as Western Europe. In absolute figures the gas consumption in Western Europe by the year of 2020 is expected to reach 625bcm/a. Of this quantity about 30% might be covered by the domestic production of the countries. The rest Q^{im} =420bcm/a have to be imported.[20] Algeria, Norway, the African Republics, and the Former Soviet Union are the main gas exporters for the Western Europe.

For the analysis of the Eurasian gas supply, we have to distinguish the demand for the Former Soviet Union gas. A few obstacles prevent us from modelling the competition among the exporters and estimating the demand function explicitly. Exporters sign long-term contracts with buyers setting the price and quantities for the periods of 15 to 25 years. Buyer may negotiate a new contract with a supplier only after the previous one is expired. At that time, the contracts with the other suppliers may still be valid. Moreover, export contracts are confidential on their nature. One can reveal the quantities to be exported through the capacities installed, but the information on the prices is missing.

We propose to estimate the demand for gas of the Former Soviet Republics based on the information on capacities and marginal costs of all exporters. As a rule, gas producers export their gas up to the capacity limit.[21] For every capacity level, producers have different marginal cost. We use the data on costs and capacities from Observatoire Mediteranen de L'Energie(2003), see Appendix 2, to build an aggregate supply function $S(p)$. We arrange the producers by costs, starting with the cheapest one. In this row the next most expensive producer after Russia is LNG producing Oman. Then, we assume market clearing mechanism $S(p) = Q^{im}$, for Q^{im} is exogenously given. Thus, producers bid the reservation price equal to their marginal cost plus some mark-up and and sell gas at market clearing price. Under the reservation price producers sell gas up to their capacity or up to demand.

[19]EU15 includes Austria, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, Switzerland, and the UK. We look at the market formed by these countries as a whole, without specifying demand for each individual country.

[20]We take the figures for the consumption presented by International Gas Union Report (2006).

[21]Source: Observatoire Mediteranen de L'Energie(2003), see Appendix 2

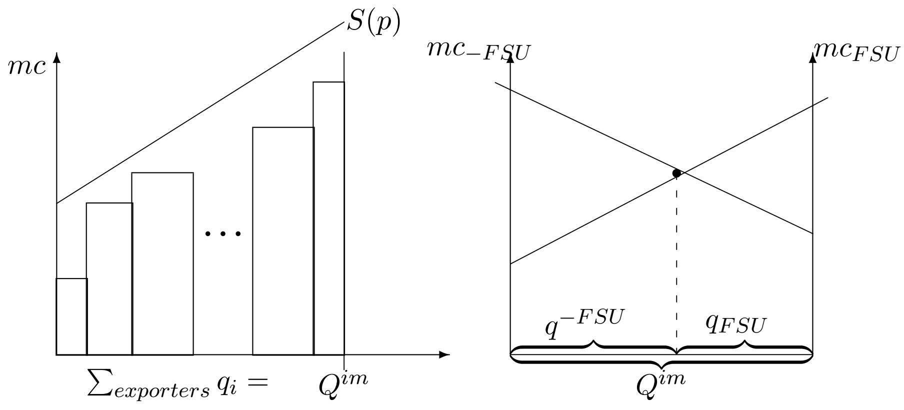


Figure 2: Gas supply curve

We assume a linear form of the inverse residual demand function: $p(q) = \alpha - \beta q$ for FSU gas. Taking the quantity q_{-FSU} set by the cheaper producers as a given, we find $p(q)$ as the residual demand. We calibrate the demand function given the condition $p(q = 0) = p_{LNG})$. This implies a 20% mark-up.[22] Finally, we obtain α =175$/tcm and β is equal to 0.30. Hence, for a prospective export of 140bcm/a the price of the Former Soviet Union gas will be about 130$/tcm.

Given the parameters of the inverse demand function we obtain the price elasticity of demand $\varepsilon = -2.6$ for the optimal supply level for the grand coalition 160bcm/a. The quite elastic demand reflects the flexibility of the European buyers in the choice of a producer in the long-run. The exporters are tight by the contracts in the short term, but they compete in the long term perspective. The obtained elasticity is close by the value to the estimates for the European market provided by Boots, Rijkers, and Hobbs (2004).

Production costs Production cost are the costs of gas extraction and depend on terrain, climate conditions as well as infrastructure on place. The costs vary with fields and specified for each producer individually. Let the producers allocate gas production as to minimize their costs. This implies an increasing function for the marginal production cost, which we assume to be linear $mc(q) = m + c \cdot q$. For Russia, we estimate the slope parameter using data on the production cost change with the increase in export quantities.[23] We find c_r=0.4, where the subscript refers to Russia as the producer. The intercept is taken to be equal to the cost of the field preservation. For Russian old depleting fields, like Medvegje it is declared about m_r=15$/tcm$.

[22]Note, we refer to the European border prices and do not reckon mark-ups of the distributors. Gas prices are opt to follow oil prices. In our estimations we reflect this relation by putting the restriction for the gas price at the oil price level.

[23]"Strategy for the Russian gas industry development" (2004) provides the data on cost raises given the export increases in Russia.

As for Turkmenistan, it claims that the price Russia pays for Turkmen gas reflects its production cost plus a normal return. Given the norm stay the same over the time, one can take the changes in price to be equal to the change in marginal costs. Then, we obtain c_t=0.35. The milder climate of the Caspian region, as opposed to that of Siberian permafrost region, results in lower preservation cost for Turkmenistan m_t=10$/$tcm$.

Finally, if the producers cooperate, they will combine their fields. Assuming, that they minimize joint production cost, we derive the joint marginal cost function: $mc_{rt} = 11 + 0.3q$ for $q \geq 14bcm$ and $m_{rt} = m_t,\ c_{rt} = c_t$ if the smaller quantities are exported.

Transportation costs Transportation costs account for operation costs and gas losses. These costs depend on the length of a pipeline and specific features of the track. The operation cost imply expenses mm on management and maintenance of pipelines and compressor stations. The gas losses present the per cent of gas g utilized by compressors on pumping to keep the pressure in pipelines. The both cost components are proportional to distance d. For the onshore pipeline the loss factor is $g = 0.25\%$ of gas per $100km$, for the high pressure underwater pipelines the figure is doubled $g = 0.5\%$.[24] The maintenance costs also differ for onshore and offshore pipeline: $mm = 0.1\$/tcm \cdot 100km$ and $mm = 0.2\$/tcm \cdot 100km$, respectively.

Total supply costs The total cost of gas supply includes production and transportation costs. We derive a simplified formula of total cost: [25]

$$tc(q_S) = \sum_{i \in S}((\frac{mm_i}{g_i} + \int_0^{q_S} mc_j(q))e^{g_i \cdot d_i} - \frac{mm_i}{g_i})q_i \tag{9}$$

transport cost parameters are specified for a particular pipeline. In our case every pipeline is associated with one player i, so we spare on indexes and put i to denote the pipeline. The marginal production costs imply a particular producer j.

Investment cost In the previous paragraphs we dealt with annual cost figures, but investment costs of pipeline projects are usually given in total. To annualize investment we use the following formula: $I_i = \frac{r \cdot \bar{I}_i}{(1-(1+r)^{-t})}$, where $\bar{I}_i$ is the total investment per capacity. We take the real interest rate for investment to be $r = 0.15$. The approximate lifetime of pipes is $t = 25$ years.

We distinguish two types of investment projects: projects to increase capacity of an installed pipeline and projects to build a new pipeline. The first type of projects include installation of extra

[24]See Oil, gas and coal supply outlook (1995) for further explanations of the transportation technology.

[25]We take, that the total cost of supply should include all the expenses on the way:

$$\frac{tc(q, d + \triangle) - tc(q, d)}{\triangle d} = mm + g \cdot tc(q, d) \tag{8}$$

We solve the differentiation equation and substitute the production cost for the cost at zero distance. For further details see Hubert, Ikonnikova (2004).

compressor stations and can be completed within months. As for a new pipeline, it might take two or three years, before the pipeline goes into operation and can deliver gas. To take this delay into account we add a multiplier $(1+r)$ to the investment cost of new pipelines: $(1+r)I_i$. We present

Table 1: Description of the links

Link[a]	capacity k_l[bcm/a]	investment cost I_l[\$/tcm]	distance d[100km]	supply cost tc(1tcm)[\$]	countries, forming a supply chain
Souyz	70	sunk	16	17.2	Russia, Ukraine
Yamal1	28	sunk	16	17.2	Russia, Byelorussia
Upgrade	15	7.7	16	17.2	Russia, Ukraine
Yamal2	∞	15.2	16	17.2	Russia, Byelorussia
NEP*	∞	24.9	16	17.2	Russia
TCP*	30	23.7	38	15.0	Turkmenistan, Azerbaijan
Nabucco*	30	23.7	38	15.0	Turkmenistan, Iran

[a]We mark with a star the projects of new pipelines

the figures for supply and investment costs for the investment options under the consideration in the table1. The first two rows of the table describe the existing pipelines in Ukraine and Belarus. Their capacities are fixed and investment costs are sunk. The next two links are the extension of the first two pipelines: Upgrade of Ukrainian pipeline system and the second band of the Yamal project. These two investment projects are the cheapest investment options, as one may see from the second column of figures. To organize supply through the pipelines in Ukraine and Belorus, Russia is required.

The technology of pipelines implies some economies of scale. The economies of scale appears thanks to the existing infrastructure. Thus, it is cheaper to extend a pipeline or lay a pipeline parallel to the existing track, than to build a pipeline opening a new path. Onshore pipelines are cheaper to build than offshore pipelines due to the installation difficulties. Another reason for high investment cost is the length of track. As the result the last three pipelines are the most expensive ones.

As one can see from the second column, we fix the capacities of the TCP, Upgrade and Nabucco projects. If more capacity to be added, the extension of the rest of the connected transmission network (e.g. the complement pipelines in East Europe and Turkey) will be required. This will lead to increase in projects' costs. In contrast, the Yamal2 and NEGP directly join with the European gas network. Europe is assumed to adjust the internal grid to the import needs on its own, no restrictions are put on the pipelines going direct to the EU border.

5 Results

5.1 Partition function

We substitute the demand, supply, and investment cost parameters into the profit function (7) and calculate the values of the partition function. Recall, the values of the partition function show the profit, which the players of a given coalition can achieve playing against the outside coaltiions. The coalitions are involved into the Cournot competition. In addition, we determine the capacities installed by the coalitions and obtain the quantities delivered to the market. In the table 2 we give the profits of the essential coalitions, i.e. the coalitions including at least one producer. The equilibrium capacities of the coalitions are given with respect to the investment projects available. We use the sign "-" to mark the pipelines, which are not available. The complete table of coalitional profits with respect to availability of pipelines is presented in the Appendix 3.

Table 2: Production plans, prices, profits

partition	capacity on links bcm/a							price	profit[a]	% of total
	Uold	Yam1	Yam2	Uup	NEGP	TCP	Nab	\$/tcm	\$bn	
$\{\{r\},\{t\},..\}$	-	-	-	-	130	-	-	136	8.7	65%
$\{\{r\},\{t,a,i\},..\}$	-	-	-	-	113	30	30	124	6.5; 4.4	49%; 33%
$\{\{r,t\},..\}$	-	-	-	-	150	-	-	130	10.3	77%
$\{\{r,b\},\{t\}..\}$	-	28	112	-	0	-	-	133	10.4	78%
$\{\{r,b\},\{t,a,i\}..\}$	-	28	94	-	0	30	30	120	8.1; 4.2	60%; 31%
$\{\{r,t,b\},..\}$	-	28	132	-	0	-	-	130	12.2	91%
$\{\{r,u\},\{t\}..\}$	70	-	-	15	45	-	-	136	10.7	80%
$\{\{r,u\},\{t\}..\}$	70	-	-	15	-	-	-	150	9.6	72%
$\{\{r,u\},\{t,a,i\}..\}$	70	-	-	15	27	30	30	124	8.5; 4.4	63%; 33%
$\{\{r,t,u\},..\}$	70	-	-	15	65	-	-	130	12.3	92%
$\{\{r,b,u\},\{t\}..\}$	70	28	27	15	0	-	-	133	11.6	87%
$\{\{r,b,u\},\{t,a,i\}..\}$	70	28	9	15	0	30	30	124	9.2; 4.1	69%; 30%
$\{N\}$	70	28	47	15	0	0	0	127	13.4	100%

[a] If two coalitions $\{S_1, S_2\}$ in the partition earn non zero profit, we give the profits of these coalitions respectively π_{S_1}; π_{S_2}

The figures in the table reveal the significance of some pipelines. When the producers stay separate and do not cooperate with any of the transiters, Russia earns 65% of the grand coalition profit investing in the Baltic pipeline. The comparison of the first and the second rows shows, that NEGP pipeline brings 1.6bn more if the producers cooperate. The greater the profit the producers can earn on their own, the smaller the contribution of the transiters into the profit of the grand coalition and the less their payoff. Given, that NEGP project is available the share of the transiters is limited by 23%. Hence, Russia gains a strong bargaining position with the transiters keeping NEGP as an outside option.

If the cooperation of Russia with Turkmenistan fell through, the competition with Turkmenistan and the loss of more efficient production fields would reduce the profit of Russia by almost a half. On the one hand, this reduction is the contribution of the Turkmenistan to a coalition with Russia, on the other hand, the significance of TCP and Nabucco projects for the Caspian producer. Whatever the coalition structure forms, if the Caspian players cooperate and can build TCP and Nabucco, their stand alone value guarantees them at least 30$ of the grand coalition profit. If the projects of the Caspian pipelines are abandoned, contribution of Turkmenistan is determined by the synergy. The Caspian transiters can earn nothing. Thus, TCP and Nabucco grant the Caspian players a strategic advantage in bargaining with Russia and the other transiters.

One should note, that the positions of Ukraine and Belorus as well as Azerbaijan and Iran depend on their complementarity to the producers. The more capacities a transiter has, the greater his contribution, the higher his payoff. Thus, due to the capacity constraint, 70bcm/a plus 15bcm/a, Ukraine loses in comparison with Belorus more than 1bn. Furthermore, the value of capacities depends on the substitutable capacities available. For instance, the Upgrade and the Yamal pipelines lose a large part of their value in the presence of NEGP, TCP, and Nabucco pipelines.

Robustness of results The relative values of the coalitions do not change significantly if the quantitative parameters of our model change in the range of 10%. We compare the per cent of the grand coalition profit, which coalitions earn, for different values of the demand intercept $\alpha =$160, 175, 190 and the slope $\beta = 0.3, 0.35$. We find that the change in profit values of the grand coalition does not exceed 2.5%. We have also checked, how the figures in the last column of the table will change if the slope of the unit production function for producers will change by 0.05, so that $c_r = 0.45, 0.35$ and $c_t = 0.25, 0.35$. Lower production costs will increase the profit of grand coalition to 14.1bn. Yet, the profit of different coalitions in per cent does not change. The increase in the production cost, will lead to lower absolute figures. The profit of the rand coalition will be 12.8bn. Under the competition, supply coalition with Russia and Turkmenistan will earn 8.6bn and 3.9bn, respectively. However, the relative the contributions the players will remain the same.

5.2 Strategic value of pipelines

In this section, we proceed with the analysis of the strategic value of the investment options.[26] In particular, we study, how the possibility to build various pipelines affects the bargaining power

[26] All the calculations were make using the Mathematica 5.1 software, produced by Wolfram research. The files with results can by inquired from the author.

of players. We show how investments in the development of the network are not based on the cost analysis, but made for strategic reasons. We interpret shares of players in the total profit as bargaining power. Then, we assess the strategic value of a pipeline by the change in the players' shares. To pick out the value of a particular pipeline, we calculate expected payoffs of the members of the Eurasian gas supply network changing the availability of different investment options. The

Table 3: Payoffs and bargaining power w.r.t. availability of pipelines

	status quo		+ Upgrade		+ Yamal2		+ NEGP		+ TCP		+ TCP&Nab	
Russia	5907	51%	6372	52%	7636	57%	10706	84%	5267	42%	4646	36%
Turkmenistan	286	3%	358	3%	645	5%	803	6%	1468	12%	2374	19%
Ukraine	3845	33%	4309	35%	1827	14%	872	7%	3361	27%	2872	22%
Byelorussia	1449	13%	1317	10%	3177	24%	349	3%	1262	10%	1089	9%
Azerbaijan	0	0%	0	0%	0	0%	0	0%	1182	9%	905	7%
Iran	0	0%	0	0%	0	0%	0	0%	0	0%	905	7%

[a]

	all		- Upgrade		- Yamal2		- NEG		- TCP		- TCP&Nab	
Russia	8917	67%	8833	67%	8573	66%	5985	45%	9938	74%	11144	83%
Turkmenistan	1961	15%	1959	15%	1928	15%	2161	16%	1400	10%	868	6%
Ukraine	747	5%	661	5%	1008	8%	1866	14%	737	6%	727	5%
Byelorussia	642	5%	703	5%	304	2%	2010	15%	673	5%	658	5%
Azerbaijan	560	4%	558	4%	579	4%	688	5%	630	5 %	0	0%
Iran	560	4%	558	4%	579	4%	688	5%	0	0%	0	0%

[a]Demand function has intercept 175 and slope 0.3

results of our computations are presented in the table 3. The table consists of two parts. In the upper part we look at changes in bargaining power changes when investment options are added by ont at a time. We start with the "status quo" variant, with only existing pipelines available. In the lower part of the table we consider the effect of removal of investment options. The first variant "all" implies, that all known investment projects are available. By the name of the variant we designate, which investment option is added or removed. In each variant, for every player, we give two figures: an expected payoff in mln/a, and a share in a total profit in per cent.

The two parts of the table present two perspectives on bargaining. The "status quo" variant is a short-run perspective of sharing, the zero point of the bargaining, when only existing capacities are taken into account. In a long-term sharing perspective, the players have to take into account pipelines, which can be built. In the ultimate case, "all" the investment projects are to be included into consideration. The comparison of "status quo" and "all" variants reveals the difference in the shortsight and farsight view on the bargaining. It highlights the value of the portfolio of pipeline projects for the players. Though one may ague, that the true values are somewhat in between.

At present gas producers depend entirely on the transport capacities of Ukraine and Byelorussia. Therefore, Russia yields to the transiters almost a half of gas export profits. Between the transiters this half is shared according to their capacities. Thus, Ukraine has more than twice as much capacity as Byelorussia and obtains more than two times greater share. In contrast, if the investment options to extend the network are accounted, the picture changes significantly. In the "all" the producers gain 25% in power, while transiters, increased in number, lose their advantage. The transiters are left with less than 20% of the profit of the grand coalition.

Recall, the *Upgrade* is the most efficient investment option and may increase the network capacity by 15bcm/a. Comparing the figures in "+ Upgrade" and "status quo" columns one can see, that the option brings a slight shift in the profit sharing. Ukraine strengthens its bargaining position by 2% at the expense of Belorus. The option does not affect the positions of Russia and Turkmenistan. The strategic role of the *Upgrade* is also negligible in the context of all the other options included. It is a small change in figures between "all" and "- Upgrade". Hence, the withdrawal of the option does not change the balance of bargaining power. Ukraine loses less than 1% and keeps its position, so do the others. The Upgrade project turns out to be of no importance to the players of the network.

The strategic value of *Yamal* project is a bit different. If the option is added to status quo, it strengthens the bargaining position of Belorus with respect to Ukraine. Belorus enjoys 11% increment in its share, while Ukraine loses 19%. The increased substitutability between the transiters grants the producers with 8% of the profit. However, the strategic value of the option decreases if it is considered in the context of all the options. Russia loses 1%, as Ukraine loses 2% at cost of Russia and Belorus. Thus, the investment in Yamal2 gives a moderate strategic advantage to Belorus only. Therefore, Russia does not show much interest in the extension of the track.

In contrast to the Yamal and Upgrade projects, the appearance of the North European Gas pipeline changes the bargaining situation dramatically. Recall, that the pipeline has long been seen to be inefficient. Yet, it allows Russia to bypass its transiters and thus, to damage their bargaining position. Russia increases its share in the profit by 2/3, the share of the transiters will decrease to 10%. The great impact of NEGP on the balance of bargaining power can also be observed in the lower table. If the option were abandoned, Russia would lose 1/3 of its payoff, that is almost $3bn would be redistributed between its transiters. So, the gain in power and in the expected payoff explains why Russia considers the NEGP as a highly beneficial project. Though it looks inefficient in comparison with the Upgrade and Yamal2, it brings more profit, than these two projects together.

So, far we have not seen a significant change in the share of Turkmenistan. It keeps its weak position vis-a-vis Russia, as long as it cannot market its gas, but through Russia. Yet, the appearance of the TCP and Nabucco pipelines bring a tremendous shift in the position of the Caspian producer. As the NEGP for Russia, the pipelines bypassing Russia and opening an access to the European market are of great importance for Turkmenistan. Its share, together with the payoff, jumps in almost 10 times from \$285mln to \$2374mln on "status quo" background. The threat to be involved in additional competition makes Russia give up a part of its profit. Thus, the possibility to supply its gas independently of Russia increases the share of Turkmenistan by 9%, if one and by 16% if the both pipelines are presented. At the same time, Ukraine and Belorus also forfeit a part of their profit to the new transiters. The strategic value of the Caspian pipelines is considerable in the context of "all" the options too. Altogether the Caspian players gain a 17% advantage in bargaining with Russia thanks to the TCP and Nabucco pipelines. This explains why the Caspian players have expressed eagerness to develop the project of new pipelines, which even less efficient than the pipeline through the Baltic sea.

Equilibrium partition Besides expected payoffs to the players we determine the equilibrium partition of players into coalitions. We find, the grand coalition always forms if the players have "status quo" plus one more investment option for supply. This result is a collection of several finding. First, any transiter prefers to join a coalition of the complement producer. In general, the gross marginal contribution of a player to a coalition with higher complementarity is greater, than the contribution of the player to any rival coalition. The complement coalitions gets the advantage in competition and becomes more efficient (or less capacity constraint). The rival gain is the advantage in competition, as a coalition playing against him reduces its supply possibilities. For instance, if Belorus joins $\{t, a, i\}$ Russia loses 1.6bn while the profit of the Caspian players increases by only 0.2bn. If Azerbaijan and Iran join Russia, Turkmenistan loses 4.4bn, when Russia gains only 2.2bn. Like transiters, producers join the transiters with higher degree of complementarity. Furthermore, as the cooperation gives the producers a monopoly position (with respect to the residual demand) and allows to enjoy the cost reduction in production, the producers are opt to stay in one coalition. Compiling the two conclusions one would expect, that the grand coalition will form in equilibrium.

A more interesting result is observed for the "all" minus some investment option variants. We obtained, that the grand coalition forms only in "-NEGP" and "-TCP,Nabucco" variants. With the probability $Pr(\{N\})$ =0.98 the grand coalition forms in "all" and "-TCP" variant, with $Pr(\{N\})$ =0.99 in "-Upgrade", and with $Pr(\{N\})$ =0.82 in "-Yamal2". Except the last case, the coalition structure which forms with the probability $1 - Pr(\{N\})$is $\{\{a, i\}, \{r, t, b, u\}\}$. In the variant "-Yamal2" with the probability 0.17 the equilibrium partition is $\{\{t, a, i\}, \{r, t, b, u\}\}$.

The formation of multi-coalition partitions can be interpreted as follows. In the "all" and "-Upgrade" variants the position of Russia in the competition with Turkmenistan is weak. On the one hand, Russia is eager to increase the payoff to Turkmenistan in order to avoid the competition.

On the other hand, if Turkmenistan steps in the game after the Caspian transiters, he would have to give them a share of $w(\{t,a,i\};\{\{t,a,i\},\{r,b,u\}\})$, which would make his payoff smaller, than his contribution to $w(\{r,b,u\};\{\{t,a,i\},\{r,b,u\}\})$. Therefore, Azerbaijan, and Iran are left outside the grand coalition.

If Russia abandons Yamal2 project, it weakens its position in competition with Turkmenistan at most. The profit of the coalition $\{t,a,i\}$ exceed the opportunity value of Turkmenistan: $w(\{r,t,b,u\};\{\{a,i\},\{r,t,b,u\}\}) - w(\{r,b,u\};\{\{t,a,i\},\{r,b,u\}\}) < w(\{t,a,i\};\{\{t,a,i\},\{r,b,u\}\})$. Therefore, the Caspian players prefer to form a coalition and compete with the supply from Russia, rather than form the grand coalition.

In the situation when NEGP is not available, Russia has a weak bargaining position with Ukraine and Belorus. To gain power, Russia would attract to a coalition other players, substitutable to the two transiters. Thus, the grand coalition will form. As for "-TCP,Nabucco" variant, Turkmensitan has no other option, but to join Russia. The Caspian transiters are indifferent, as their contribution to either coalition is zero. Hence, we may say a grand coalition forms. The situation is quite similar in the case of "-TCP".

5.3 Correspondence with the reality

Our first observation concerns the formation of the grand coalition. At present the players of the Eurasian gas supply network are succeed in forming the grand coalition, as they are bound by co-operation agreements. In October 2006 Russia has singed a new agreement with Turkmenistan.[27] According to this agreement Turkmenistan will deliver to Russia 50bcm/a in 2007-2009 years on the price of 100$\$/tcm$. The new agreement was signed after long negotiations and after Turkmenistan has signed a tentative agreement with the neighbor countries on building TCP and Nabucco pipelines. The previous price for Turkmen gas was 65\$/tcm. Hence, roughly speaking, the appearance of the investment projects of the Caspian pipelines gave Turkmenistan about 1.7bn increase in profit. The same difference in the payoff of Turkmenistan can be observed in the table 3 if ϕ_t for "status quo" and "all" are compared. The win in the payoff is a bit smaller, if "all" and "-TCP, Nab" are compared.

In negotiations over the transit contract, Azerbaijan asks Turkmenistan to allow to use the half of the TCP capacities for its own export. In terms of payoffs, it will mean, that Azerbaijan asks a half of the profit of the TCP project. Yet, Turkmenistan is ready only for the concession of 1/4. We obtained, that the profit of the coalition $\{t,a\}$ is 2.4bn, than 1/4 is about 600mln. Looking at the table 3, we find, that in the variant "all" Azerbaijan get the payoff of 560mln.

Another player whose predicted payoff we may compare with the real value is Ukraine. In the winter 2006 Russia expressed its intentions to reduce its net payments to Ukraine. Ukraine obtains

[27]See "The Moscow Times" issue from 26.10.2006.

26bcm/a of gas as a payment in kind for the transit and it pays Russia for 30bcm exported in addition annually. Recall, at the same moment the building of NEGP has been started. Russia would have liked to raise the price for gas exported to Ukraine from 65$/tcm to 230$/tcm. Yet, after long negotiations the price of 95$/tcm for 2006 and 130$/tcm for 2007 was set. Given the alternative to supply Ukraine is to supply Europe, we calculate the net payoff to Ukraine reduces from 5bn to less than 2bn in the year of 2007 and less than 1bn is by 2015 the price of 230$/tcm will be reached. Note, that though the theoretical "status quo" payoff seems to be lower, the relative change is roughly coincides with the reality.

We can not say much about Belorus, as the renegotiations of the current contract are at progress. Yet, we may note, that Belorus is likely to agree on the increase in price for Russia gas if the gradual schedule, as for Ukraine, will be developed. It is also difficult to talk about absolute payoff of Russia, as most of the profit data are confidential. However, the previous remarks on the negotiations of new contracts with the transiters allow to conclude, that Russia gains with appearance of NEGP a lot.

6 Conclusions

In general it is difficult to apply the solutions of the partition function form games to real world analysis. One should be able to calculate the outcomes of the game under all possible contingencies, the optimization problem of every conceivable sub–coalition of players has to be solved. Moreover, the number of possible coalitions grows rapidly as the number of players increases. Furthermore, many of the possible sub–coalitions would have to deal with situations which are very different from those prevailing in reality. This raises the problem of obtaining data and making predictions for rather hypothetical situations, which severely limits the practical applicability of most of the solution concepts.

In the paper we introduce an approach, which can be applied to a wide range of situations. We test it on the example of the Eurasian gas supply network. Fortunately, in the Eurasian gas transmission system the number of truly independent players is small and the options of the various coalitions can be easily derived from the geography of the transmission grid. Furthermore, the technology of pipeline transportation is fairly straightforward allowing rough estimations of the cost of the various options. In fact, all projects which have to be considered for the theoretical analysis have been already proposed in real life in one form or another – often with detailed cost estimates. In this sense, the Eurasian gas transmission offers a rather unique opportunity to assess the usefulness and prediction power of the coalitional bargaining model of Maskin (2003) in applied research.

In the paper we have demonstrated how the bargaining power can be assessed. We have shown the importance and role of investment decisions both for the future profits and strategic positions of the players. Taking into account all options to extend the current transport system we obtain a reasonable result on the overall distribution of profits in this supply chain. Furthermore, we quantify the strategic importance of single options. The Upgrade and Yamal2 pipelines, may look as the most efficient projects to extend the network at first glance. Yet, we find, that these projects strengthen the positions of the transiters, Ukraine and Belorus, and do not bring any advantage to the investing party, i.e. Russia. The competition between Belorus and Ukraine is of little strategic importance compared to an option for direct Russian access to customers. The commercially unattractive NEGP has a great strategic value. It increases the bargaining power of Russia more than all other options together. The TCP and Nabucco pipelines, though very expensive, are the important investment projects too. If the pipelines are built, Turkmenistan can bypass Russia and supply its gas to the European market. Under the threat of competition, Russia is ready to increase the payoff to Turkmenistan. Hence, the pipelines contribute to the bargaining power of the Caspian producer. However, as the cooperation of the producers is profitable for both of them, the pipelines are not built, but stay as an outside option.

We see a wide range of applications of the methodology introduced. One can use it to estimate the bargaining power on the electricity market, when the players are generators and operator of the transmission lines. Following the research of Stole and Zwiebel (1998), one can assess the bargaining power of workers and firms given the job opportunities presented. The international environment agreements can be considered as coalition, which countries may form to control the emissions.

Appendix 1

Here, we define the class of situations, for which the approach of Maskin (2003) gives at least one equilibrium. Let us introduce some more notation. We will determine the gross marginal contribution of a player i into coalition S_j given the belief, that otherwise the player will join S_k as w_{jk}. In terms of the partition function:

$$w_{jk} := w(S_j \cup i; P_{S \cup i}) - w(S_j; P_{S_k \cup i}) \tag{10}$$

Further, one may construct the quadratic matrix W with elements w_{jk}. The elements of the j^{th} row of the matrix show what the contribution of the player to the coalition S_j under different believes about his allocation. The elements of the j^{th} column determine how much every coalition in the partition loses if the player joins S_j.

Then, the second axiom of allocation of the player to a coalition can be rewritten as follows:

$$S_j \to S_j \cup i \text{ if } w_{jk} \geq w_{kj} \;\text{ for } k = arg\max w_{kj} \tag{11}$$

The game has at least one equilibrium if for every subgame of the game (N, w) exists at least one S_j satisfying the axiom.

Proposition: (*Sufficient condition*) A subgame perfect equilibrium (ψ_i, P) exists if there exist two coalitions $S_j, S_k \in P$ such that

$$k = arg\max w_{kj} \text{ and } j = arg\max w_{jk} \tag{12}$$

in words, it means, that in the partition, there are two coalitions, each of which loses at most if the player is allocated to the other of two.

Proof: As $k = arg\max w_{kj}$ then we compare w_{jk} with w_{kj} when decide whether the player will be allocated to S_j. If $w_{jk} \geq w_{kj}$, then we find the equilibrium allocation and can assign a payoff. If $w_{jk} < w_{kj}$, then the player is allocated to S_k, because $j = arg\max w_{jk}$ and we compare the same figures.

The condition of the proposition holds for any game with $n \leq 3$, as at most two coalitions will compete for a player. Therefore, the equilibrium of the (N, w) game will exist. An equilibrium also exists in the game with ≤ 2 essential players. By essential players we mean such players i that

$$w(S; P) = \begin{cases} 0 \text{ if } i \notin S \\ w(S; P) \text{ if } i \in S \end{cases} \tag{13}$$

The Eurasian gas supply network is an example of the game with the two essential players. The essential players are the producers, without cooperation with producers transiters will earn zero profit on the market. Thus, according to the proposition we may say, that in our game at least one equilibrium always exists.

Appendix 2

Supply cost are calculate with respect to distance to the EU borders. The costs include production and transportation cost.

Appendix 3

In the table5 there are the profits of essential coalitions, that is the coalitions including producers. Coalitions without producers earn only zero profit. The profits of coalitions are given with respect to the investment options available. The first part of the table starts with the variant "all". In this variant all the investment options discussed are available. In every next variant we exclude the option given in the title from the consideration. Thus, "-Upgrade" means, that the players can not invest in the upgrade of the old Ukrainian system. The second part of the table take "status quo" variant as a basis. In this variant only existing pipelines are considered. Every next row allows to invest in the pipeline marked in the title. For instance, "+Upgrade" means, that the players can use 70bcm/a of Ukrainian old system, 28bcm/a of the Yamal1, and invest in the Upgrade with the capacity of 15bcm/a.

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Table 4: Supply costs and capacities of EU exporters

expoter	cost[a] $/tcm	capacity bcm/a
Algeria via Medgaz	39	20
ALGERIA via GME	49	10
ALGERIA via Sardinia-Corsica	49	10
ALGERIA via Transmed	55	24
LIBYA via pipe to Sicily	60	30
IRAQ via Turkey	71	17
NORWAY-North Sea Satellites-Pipe	72	20
IRAN via Turkey	78	11
NORWAY-North Sea -Pipe	79	40
ALGERIA-LNG	87	10
EGYPT LNG	92	25
LIBYA LNG	94	4
QATAR LNG	107	20
NIGERIA LNG	108	19
VENEZUELA-LNG	108	3
TRINIDAD n' TOBAGO-LNG	108	4
YEMEN LNG	110	4
IRAN LNG	110	5
UAE LNG	111	3
OMAN LNG	114	6
NORWAY-Barents Sea LNG	124	17

[a]Source: Eni's Annual Report (2005), Observatoire Mediterraneen de L'Energie (2002), Robert (2003), and Stern (2006)

Table 5: Coalitional profits in \$bn

		$\{t\}$	$\{t,a\}$	$\{t,a,i\}$	$\cup\{t\}$		$\{t\}$	$\{t,a\}$	$\{t,a,i\}$	$\cup\{t\}$
$\{r\}$	all	8.7; 0	7.5; 2.5	6.5; 4.4	10.3	status quo	0; 0	0; 0	0; 0	0
	-Upgrade					+Upgrade				
	-Yamal2					+Yamal2				
	-NEGP	0; 0	0; 3.6	0; 6.4	6.6	+NEGP	8.7; 0	8.7; 0	8.7; 0	10.3
	-TCP		8.7; 0			+TCP		0; 3.6	0; 3.6	3.7
	-TCP,Nab		8.7; 0	7.5; 2.5		+TCP,Nab		0; 3.6	0; 6.4	6.6
$\{r,b\}$	all	10.4; 0	9.2; 2.4	8.0; 4.2	12.2	status quo	4.0; 0	4.0; 0	4.0; 0	4.2
	-Upgrade					+Upgrade				
	-Yamal2	9.4; 0	8.2; 2.5	7.2; 4.4	11.0	+Yamal2	10.4; 0	10.4; 0	10.4; 0	12.2
	-NEGP					+NEGP	9.4; 0	9.4; 0	9.4; 0	11.0
	-TCP		10.4; 0	9.2; 2.4		+TCP		3.8; 3.4	3.8; 3.4	7.1[a]
	-TCP,Nab		10.4; 0	10.4; 0		+TCP,Nab		3.8; 3.4	3.5; 5.9	9.3[b]
$\{r,u\}$	all	10.7; 0	9.5 ; 2.5	8.5; 4.4	12.3	status quo	8.6; 0	8.6; 0	8.6; 0	9.1
	-Upgrade	10.4; 0	9.3; 2.5	8.2; 4.4	12.0	+Upgrade	9.6; 0	9.6; 0	9.6; 0	10.4
	-Yamal2					+Yamal2				
	-NEGP	9.6; 0	8.9; 2.9	8.0; 4.9	10.4	+NEGP	10.4; 0	10.4; 0	10.4; 0	12.0
	-TCP		10.7; 0	9.5; 2.5		+TCP		7.9; 3.0	7.9; 3.0	10.9[c]
	-TCP,Nab		10.7; 0	10.7; 0		+TCP,Nab		7.9; 3.0	7.2; 5.1	12.0[d]
$\{r,b,u\}$	all	11.6; 0	10.4; 2.4	9.2; 4.2	13.4	status quo	10.6; 0	10.6; 0	10.6; 0	11.5
	-Upgrade	11.5; 0	10.2; 2.4	9.1; 4.2	13.3	+Upgrade	11.2; 0	11.2; 0	11.2; 0	12.4
	-Yamal2	11.4; 0	10.2; 2.5	9.2; 4.4	13.0	+Yamal2	11.5; 0	11.5; 0	11.5; 0	13.3
	-NEGP					+NEGP	11.1; 0	11.1; 0	11.1; 0	12.7
	-TCP		11.6; 0	10.4; 2.4		+TCP	10.6; 0	9.7; 2.8	9.7; 2.8	12.5[e]
	-TCP,Nab		11.6; 0	11.6; 0		+TCP,Nab	10.6; 0	9.7; 2.8	8.8; 4.6	12.8[f]

[a]Here we put the value $w(\{r,t,b,a,i\};\{\{r,t,b,a,i\},\{,u\}\})$

[b]Here we put the value $w(\{r,t,b,a,i\};\{\{r,t,b,a,i\},\{u\}\})$

[c]Here we put the value $w(\{r,t,u,a,i\};\{\{r,t,u,a,i\},\{b\}\})$

[d]Here we put the value $w(\{r,t,u,a,i\};\{\{r,t,u,a,i\},\{b\}\})$

[e]Here we put the value $w(N;\{N\})$

[f]Here we put the value $w(N;\{N\})$