# Hold–Up, Multilateral Bargaining, and Strategic Investment:

# The Eurasian Supply Chain for Natural Gas.

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**Abstract**

We analyze how investment into the pipeline system supplying Russian natural gas to Western Europe is distorted for strategic reasons. We use a two stage multilateral bargaining game among heterogenous players, some lacking the ability to make long–term commitments. At the first stage the players negotiate contracts over access rights and investment. At the second stage investment cost are sunk, capacities are given and the players bargain about the sharing of rents from previous investment. Our qualitative and quantitative analysis predicts excess capacities in equilibrium and explains overinvestment on some tracks and underinvestment on others as an attempt to create countervailing power.

Keywords: Hold-up, Multilateral Bargaining, Strategic Investment, Vertical Supply Chain, Recontracting
JEL class.: L95, L14, C71

# 1 Introduction

Ever since the Soviet Union began to deliver natural gas to Western Europe, policy makers raised concerns about energy security and strategic dependence. In the seventies and eighties a huge transport system was created linking fields in permafrost regions of Siberia to the main pipelines in Western Russia and further on to customers in Western Europe.[1] The importing countries often contributed in–kind to investment cost by providing pipes and compressors and were entitled to steady gas deliveries under long–term agreements, typically ranging from 15 to 25 years.[2] The US-government strongly resented this development arguing that Western Europe would become vulnerable to blackmail and extortion. However, when the Soviet block finally disintegrated, no attempt had been made to exploit Western Europe's increasing energy dependency and Russia fullfilled its contractual obligations throughout the ensuing internal turmoil.

Security of gas supplies remained an issue, though. For the delivery to the lucrative markets in Western Europe, Russia depends now on transit through newly independent states, such as Ukraine, Poland, Belorussia and others. In March 2004, for the first time in history, Russia deliberately shut off supply along the newly built Yamal pipeline in order to force a transit country, Belorussia, into compliance. The dispute is essentially over the sharing of profits from exports and similar to earlier conflicts with Ukraine. Today, energy security is closely related to the strategic control of transit pipelines. Recent investments in the Eurasian transmission network as well as plans for further pipeline connections reflect to a large extent Russia's desire to strengthen its bargaining position vis-á-vis transit countries — in particular Ukraine, which inherited the only export pipeline for Russian gas from Soviet times. In the nineties the renovation and upgrading of the southern system through Ukraine would have been the cheapest way to satisfy a sluggish demand. But for strategic reasons Russia chose a much more expensive option, the new Yamal pipeline through Belorussia and Poland with a capacity which up till now is not fully used. In view of the recent disputes with Belorussia, it is quite possible, that an even more expensive offshore option through the Baltic Sea will be chosen for the planned increase in transport capacities.

Production and transportation of natural gas are characterized by large initial investment in specialized facilities with a long lifetime and low operating cost. Most of the expenditures on project identification, investment planning and construction are sunk. Hence, the installed capacities generate large quasi–rents. When deciding upon investment, the players will take into account whether others can credibly commit to share these rents in long term contracts or whether they will re-

[1] Throughout this paper we will refer to 'Western Europe' as the market consisting of the old EU-countries excluding Greece which are connected through a dense network of pipelines. For the ease of reference we often use the names of the countries instead of companies, whenever there is no risk of misunderstanding. Hence we speak of Russia rather than Gazprom, Ukraine instead of Naftogaz etc.

[2] So called 'take–or–pay' contracts regulated prices and quantities to ensure the efficient usage of the capacities and steady revenues. To account for changes in the economic environment gas prices used to be indexed to oil prices. However, over a long period of time the contracted quantities had to be paid for whether used or not, hence, the name 'take–or–pay' (Asche, Osmundsen, Tveteras (2000)). As the gas market developed, prices gained some independence from oil prices and the current drive for liberalization favors short–term contracts and third party access. In spite of these changes, it is still common that producers and importers form consortia to realize new projects under long–term agreements (Stern (2001)).

contract after completion of the investment. In case of recontracting, a player's bargaining power is increased if he is in de facto control of transport capacity. In principle, he may pay up–front for the increased bargaining power at the investment stage. However, large up–front payments may not be feasible. For example Ukraine's access to international capital markets is restricted for quite the same reasons which raise doubts about its commitment in the gas market. The cash–strapped country cannot afford to compensate others up–front for future gains in bargaining power. Hence, lack of international contract enforcement, financial constraints and limited commitment may result in the classic hold–up problem.

In this paper we analyze strategic investment in the framework of a two stage multilateral bargaining game among the members of the supply chain. At the first stage the players form coalitions, negotiate contracts over access rights and invest in transport capacities. At the second stage investment cost are sunk, capacities are given and the players bargain about the sharing of the rents from previous investment. We assume that contracts at the second stage are complete with respect to prices and quantities, as is required for the efficient use of the existing network. As the number of players is small and the basic technologies of gas transport are well–known, the members of the Eurasian supply chain are assumed to bargain efficiently and to make the best use of the existing transmission network. This allows us to use the Shapley value, a well–known solution concept for multilateral bargaining, to calculate the sharing of profits in the supply chain. The relative size of payoffs indicates the strength of the players' positions. Hence, we derive the bargaining power of the parties in a very natural way from the features of the transmission grid.

As to investment at the first stage, however, it is not always impossible to write credible long–term contracts to prevent recontracting. Otherwise, bargaining over rents would never occur because everything would be stipulated in advance. We assume that players are heterogeneous in the sense, that some can credibly commit to comply with obligations in the future, while others will recontract if it is in their interest to do so. Russia, for example, has worked hard to establish a reputation for reliability in this market for almost three decades. It would loose this reputation if it defaulted on its obligations to achieve short run gains. Others are heading towards EU integration, making it essential to be accepted as a reliable partner in business matters. Ukraine, in contrast, has no record of honoring long–term agreements. As a newly founded state it would have to forgo short–term benefits now in order to build up a reputation for honesty in long–term business relationships what pays off only in the distant future. Given the fragility of its political system, it appears highly unlikely that other players would trust any long–term commitment at face value.

The qualitative analysis of a simple model of the transportation grid shows that investment into links which cannot be covered by contracts is decreased, while investment into alternative but more costly options is increased in order to create countervailing power. Depending on the relative strength of these effects and on capacity cost there will be (i) underinvestment, (ii) distorted investment in the sense that more costly options are chosen, (iii) overinvestment, in the sense that total capacity is larger than under full commitment, and even (iv) excess capacity which will be left idle at the production stage.

The Eurasian transport system for natural gas offers a unique opportunity to put theoretical results to an empirical test. The various investment options and the associated cost are sufficiently clear to allow for a quantitative specification of the parameters and to confront the results with the historical evidence. The quantitative analysis suggests that strategic reasons do in fact justify the neglect of the old links in the South running through Ukraine and the investment into the new Yamal pipeline, with capacities well above what was needed at that time. In this sense we are able to explain the recent investment pattern of the industry.

In its spirit, the paper is obviously related to the large literature on hold–up and second sourcing. Most of this literature assumes that contracts are incomplete due to information problems, which limit external enforcement by a third party. Possible remedies arise from the fact, that an enforcing agency may observe at least some relevant features, which then can be incorporated into the contract as a substitute to improve efficiency. However, investment in transport capacity for natural gas is verifiable, and so are most contract violations during the operating stage. Hence, from the technical side, there appear few reasons to assume that contractual incompleteness and the resulting hold–up problem are of particular relevance in this market. This is confirmed by the fact that, historically, the Eurasian transmission system was developed under long–term agreements. The difficulty arises from the fact that the players involved are sovereign nations or firms strongly connected to their respective governments. In some countries, the separation of business and politics has not been firmly established and there is no truly independent legal system. As there is also no international arbitration system, legal remedies are hardly available even if it is plainly clear who is breaching the contract. Since external enforcement of the agreements is insufficient, commitment can be only credible if players are sufficiently concerned about their reputation.

In this sense the paper is closer to the literature on tax competition among sovereign states (e.g. Janeba (2000)). The focus on multilateral bargaining among heterogeneous players, the explicit modelling of restrictions on contracting in coalition formation, and the quantitative application, however are all novel. While there is a small literature exploring the strategic implication of Shapley bargaining for choice of technology and merger in general models (Inderst & Wey (2001), Jeon (2002)), we are not aware of previous usage of the Shapley value in applied quantitative studies of industrial organization.

Finally, the paper can be related to the literature on the gas–industry. Grais & Zheng (1996) and Chollet & Meinhart & von Hirschhausen & Opitz (2001b) provide a quantitative analysis of the strategic interaction in transmission systems for gas. None of them derives the bargaining power endogenously from the architecture of the transmission system. Instead, they assume that Russia has all the bargaining power but is restricted to set simple linear prices, while transit countries determine quantities. Due to double marginalization, the quantities supplied to the markets in Western Europe may be inefficiently low. In this sense 'excess capacity' is explained by inefficient contracting at the rent–division stage. Hubert & Ikonnikova (2003) analyze multilateral bargaining in the gas industry as a one–stage game, assuming that contracting about investment is efficient. By exogenously restricting investment options, they assess the strategic value of each option, but they cannot explain inefficient investment.

We limit our attention to the Russian supply chain of natural gas, which provides a quarter of the consumption in the region and more than 40% of its imports. Russian natural gas competes mainly with gas from Norway accounting for 25% of imports and low cost fields in Algeria with a share of 30%. Algeria is connected to Spain and Italy through pipelines and has the additional option to liquefy gas for shipment by tanker. Liquefied natural gas (LNG) is a rapidly growing market. Since long–range transport cost are comparatively low for LNG, new players from Africa (Nigeria) and the Middle East are expected to play an increasingly important role.[3] This raises the question how the key players, Russia, Algeria and Norway interact and how they jointly react to the threat of market entry of new LNG suppliers.[4] However, these issues are beyond the scope of this paper, which focusses on the strategic interaction within Eurasian gas chain. Hence, we model the European market non–strategically and simply assume a given residual demand for Russian gas.

In section 2 we describe the most important features of the Eurasian Supply Chain for natural gas. In section 3 we develop the theoretical approach which is then used in section 4 to provide a qualitative analysis of strategic investment. In section 5 we derive numerical results using estimations for demand for natural gas and cost of supply. Section 6 concludes.

## 2 The Supply Chain for Eurasian Gas

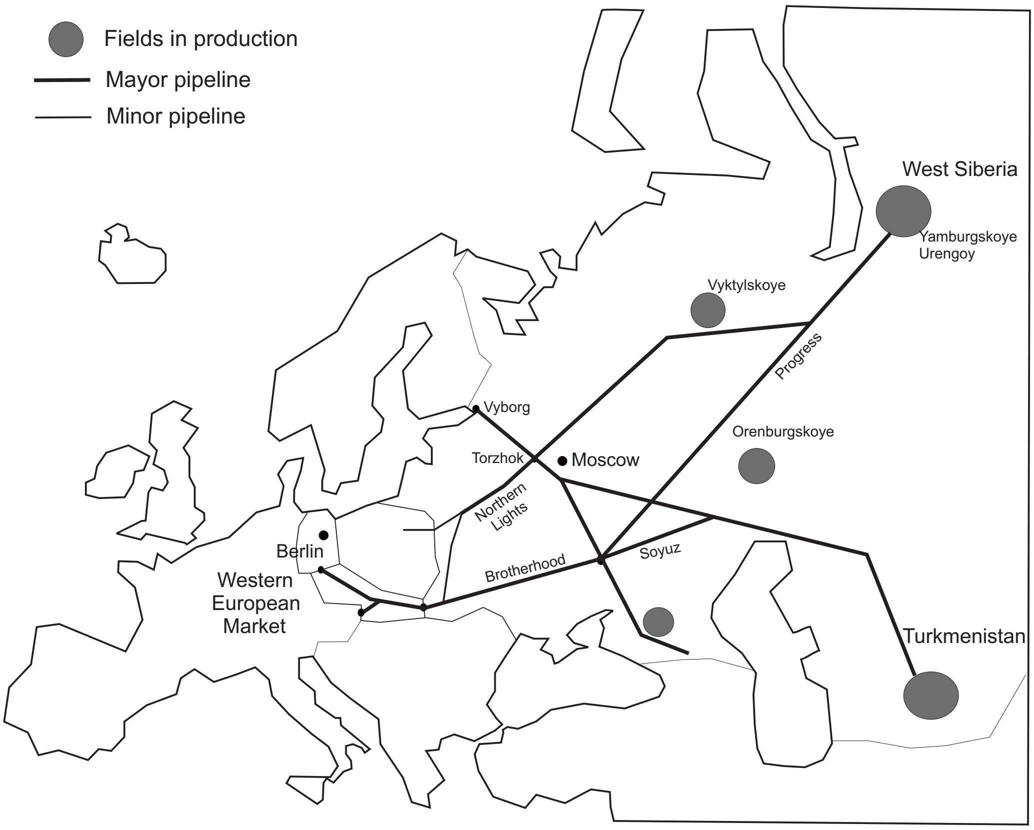
The main features of the current transmission network for natural gas have been shaped during the 70th and 80th. When the Soviet Union started to supply gas to Western Europe in the late sixties, an appendix to the Brotherhood line, transporting gas from Eastern Ukraine to Czechoslovakia was used to connect to Austria and Germany. As exports increased additional transmission capacities were established alongside previous routes, which were linked to new fields in the southern Ural (Orenburg) by the Sojus line. Surprisingly, even when production shifted northwards to Vyktylskoe and fields in western Siberia, the pipelines exporting this gas to the west took a turn towards the old routes in the south. Apparently, plans to build a new pipeline through Poland to former East Germany were abandoned in favor of the politically more reliable southern track through Czechoslovakia.

When the Soviet Union collapsed, however, Russia found itself in the uncomfortable position that

[3]The LNG infrastructure, consisting of liquefaction plants, tankers and regasification terminals, creates little dependencies between suppliers and customers, because tankers can be easily redirected. Shipment cost are roughly proportional to distance, but cost of liquefaction and regasification are independent, which makes LNG particularly competitive for long distances. For these reasons LNG received political support to avoid undue dependency on the few suppliers of natural gas. As the technique developed and cost decreased substantially in recent years, LNG developed into a commercially viable alternative. Currently it amounts only to a small fraction of imports (about 5%), but it already plays an important role in France and Spain where it accounts for 25% and 50% of imports, respectively (For details see Platts, Global Energy Report (2002) and BP Statistical Review (2002)). Opinions diverge as to the future development of LNG but with heavy investment into the infrastructure well underway, there is little doubt that LNG is set to increase its market share in the near future (Observatoire Mediterraneen de L'Energie (2002)).

[4]The current drive for the liberalization of the European gas market is expected to loosen traditional buyer-seller relations and together with increased transport capacities will probably intensify competition. The strategic interaction between the suppliers is addressed in Golombek & Gjelsvik & Rosendahl (1995) using a Cournot model and Alt & Eichengreen (1989) who look at cooperative outcomes in a repeated games context. Alt & Eichengreen (1989) take into account that the countries interact not only on the gas market but also on security issues ('multimarket contact' in terms of the industrial organization literature).

Figure 1: Eurasian Transport Network in Soviet Times

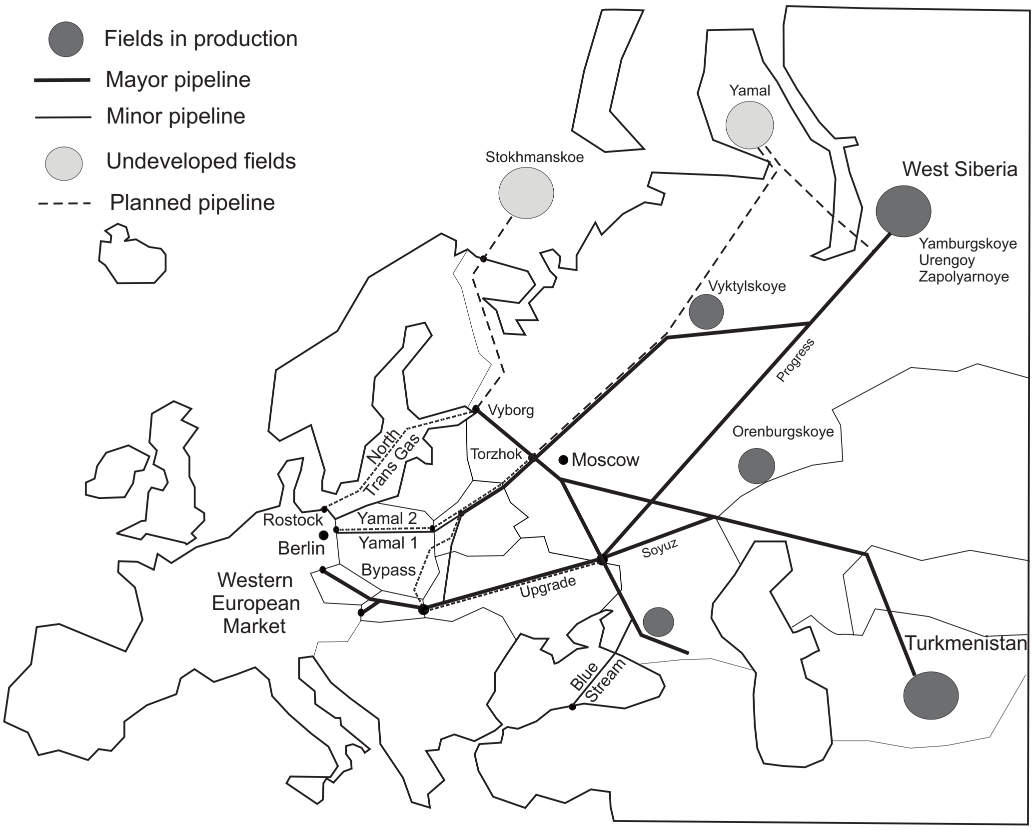



its only supply route to Western Europe passed through three newly independent states Ukraine, Slovakia and the Czech Republic.[5] Looking westward towards integration with the EU, Slovakia and the Czech Republic wanted to be seen as reliable partners who honor existing obligations. Emerging from former Czechoslovakia, these countries also benefited from old contracts with the Soviet Union, which entitled them to large deliveries of gas at low cost, thus smoothing the transition to market pricing. Both countries have been quick to privatize their transmission pipelines, the Slovakian section was acquired by the German Utility RWE, the Czech section by a consortium of Gazprom, Ruhrgas and Gaz du France. After yielding control over pipelines to the importers, these countries never attempted to use their strategic location as a bargaining chip in negotiations with Russia over gas prices.

Relations between Russia and Ukraine, in contrast, turned sour. In principle, Russia pays for transmission by supplying gas to Ukraine, approximately 26-30 bcm/a (plus an additional 6-7 bcm/a compressor gas). This payment in kind is sometimes translated into a 'transit fee' by assigning a price to the gas, but as these fees are not actually paid, they have little relevance. The conflicts are essentially over the compensation for additional 20 bcm/a, which Ukraine dearly needs

[5]For a detailed account of the ensuing conflicts and Russia's strategy see Stern (1999).

Figure 2: Current Eurasian Transport Network




but can hardly pay for. While Russia claims average European prices Ukraine concedes only half of that. But even the lower figures have not fully been paid. Ukraine is also blamed for syphoning off gas in excess to what it acknowledges officially, a claim which has some credibility, although it is strongly denied by Ukraine.

As a result of non–payments and alleged 'steeling' debts accumulated. In 2002, these amounted to $ 1.4 bn, or $ 3.5 bn, depending on which side one takes. As the dispute about non–payments for gas deliveries and accumulated debt dragged on, threats of disconnections and counter-threats of diversion have been issued. While Ukraine's excessive withdrawals interrupted gas supplies to Western Europe only occasionally and for brief periods, these episodes highlightened Russia's vulnerability and threatened to taint its reputation as a secure supplier of gas. In marked contrast to Turkmenistan, which was quick to stop deliveries when Ukraine failed to pay, Russia has little choice but to supply whatever Ukraine takes or to default on its obligations to western importers. In a recent attempt to solve the problem Ukraine payed off $ 285 mln by handing over strategic bombers and missiles, but the two sides disagreed on prices of other components of the proposed barter deal.[6]

[6]For further details see Stern (1999), Opitz, Hirschhausen (2000), Itogi (2002).

Meanwhile, due to aging compressors, lack of maintenance and underinvestment, the capacity of the transmission network, in Ukraine of which more than 70 bcm/a are used for export to Western Europe, is in decline. Recently Gazprom and Ukrainian Neftogas reached a tentative agreement according to which Russia in co–operation with German Ruhrgas would attract $ 2.5 bn to upgrade the system. By replacing old compressors the transmission capacity could easily be increased by 15 bcm/a. Existing pipelines in Ukraine have the potential for another 35 bcm/a, which would require complementary investment in Slovakia and Czech Republic. In addition, there are even plans to invest up to $ 15 bn in order to expand the system (Russian Economic Society (2002)). However, Ukraine would have to share ownership and control of its network in exchange and there is little concrete progress on this sensitive issue so far.

Eager to diversify its export channels, Russia turned to Belorussia and Poland. Initially, Belorussia' ties with Russia remained very close and its ability to act independently was fairly restricted even after gaining independence. In 1993, the two countries agreed on a long–term solution for sales and transit relationships, including the transfer of the assets of BelTransGaz, the national transmission company, to Gazprom under a 99–year lease. With Poland a joint stock company, EuroPolGaz, was established in which Polish PGNiG and Russian Gazprom hold equal shares. This enabled Gazprom to revive old ambitious plans to develop the huge Yamal field and connect it to internal and external markets with a new massive northern route.[7] However, as demand was weak during the nineties and the cost of developing Yamal turned out to be very high, the project was gradually scaled down. Eventually, attention focussed entirely on the export line, now commonly referred to as *Yamal 1*, which is built 'from the market to the field'.[8] The pipeline completed in the late nineties has a potential capacity of 28 bcm/a. Though, given the lack of demand, compressors have been installed only to support 18 bcm/a. In this sense, the project with an estimated cost of $ 3.4 bn is still running far below full capacity. At major river–crossings provisions have been made for a further doubling of the capacity up to 56 bcm/a, which would require additional investments in the range of $ 2.5 bn. However, recently Russia's enthusiasm with the project has been dampened by sharp disputes with Belorussia.

Increasing frustration with the demands of transit countries led Russia to look also for direct, though much more costly, offshore options. Early plans for a Baltic Ring, connecting Russia through Finland and Sweden to Germany have been abandoned in favor of a direct offshore connection between Vybourg (Russia) and Germany, the *North Trans Gas*. The project is currently shared by Gazprom and Finnish Fortum, but German Ruhrgas and Wintershall may join. Like the *Bypass*, *North Trans Gas* is a project on the blackboard. Planned capacities range from 18 to 30

[7] As a direct threat to Ukraine's strategic position, plans have been drawn up for a twin–pipeline with a capacity of 60 bcm/a running north–south through Belorussia, Poland and Slovakia. Since this link can also be seen as part of the larger Yamal project it is sometimes referred to as Yamal 2. Since current planning makes no provisions for additional investment towards customers in the West and fields in the east it would mainly serve to bypass Ukraine. As is shown in Hubert & Ikonnikova (2003), however, the strategic value of the *Bypass* is almost negligible, hence it will be ignored in the following analysis.

[8] Recently, the high cost of developing new fields such as Yamal or Stockman and the availability of low cost alternatives in old Siberian fields and Turkmenistan casted doubt on the economic viability of grand scale projects in the near future (Stern (1995)). Meanwhile, gas for *Yamal 1* is supplied from fields in the Siberian Basin including newly opened Zapolyarnoye.

bcm/a with cost in the range of \$ 1.7 - 3.8 bn. Commercially, the link would look more attractive if connected to Stockman, a large field which has yet to be developed. As with Yamal, the prospects for the development of Stockman are vague at best. And even if the field is developed, it might be cheaper to liquify the gas, since the cost of an onshore pipeline appear to be very high due to difficult terrain on the Kola peninsula. Nevertheless, Russia keeps pushing North Trans Gas in international negotiations.[9]

# 3 The Analytical Approach

We analyze strategic investment as a two stage game among $N$ players. At the first stage the players negotiate contracts and invest in transport capacities. At the second stage investment cost are sunk, capacities are given and the players bargain about the sharing of the rents from previous investment, some of them within the limits of contracts agreed upon at the first stage. Since players will rationally anticipate the impact of capacities along the different tracks on bargaining at a later stage, we start with the subgame dividing the rents.

Let $l(S) = \{l_1, l_2..\}$ denote the transport capacities along the various tracks which are at the disposal of a subset of players $S \subseteq N$. The corresponding quantities are given by $q = \{q_1, q_2..\}$ and $\bar{q} = \sum q$ is total supply. The maximum profit $\pi(l(S))$ which $S$ can achieve given its access to transport capacities is the value $v$ of the subset $S$.

$$v(S) = \pi(l(S)) = \max_q p(\bar{q})\bar{q} - c^o(q), \quad \text{s.t. } q \leq l(S), \tag{1}$$

where $p$ denotes the price and $c^o$ the operating cost.[10] Repeating this for every subset $S \subseteq N$, we obtain the value function $v : N^s \to R$, for the rent–division game where $N^s$ is the set of all subsets of $N$. It is worthwhile stressing, that a coalition's payoff does not depend on what the excluded players do. In other words, there are no externalities among coalitions because Russia is an essential player. Without Russia transit countries are not able to establish a complete supply chain and, therefore, neither receive any income from exporting gas nor compete with the coalition which includes Russia.

The Shapley value for the game $\{v, N\}$, denoted $\phi_i(v)$, assigns a unique payoff to every player $i \in N$. It is based on the assumption that players negotiate efficiently, form the Grand coalition, and distribute the total gains based on the expected marginal contribution of players to the various sub–coalitions $S \in N^s$. Formally, let $\Delta_i v(S) = v(S \cup i) - v(S \backslash i)$ denote player's $i \in N$ marginal contribution to sub–coalition $S$. Then the Shapley value is given as $\phi_i(v) = \sum_{S \in N^s} \alpha_S \Delta_i v(S)$, where $\alpha_S$ denotes the probability of a sub-coalition $S$, assuming that all orderings of players have equal probability. For notational convenience we extend the definition of $\phi$ to sub–coalitions and write $\phi_S(v) = \sum_{i \in S} \phi_i(v),\ S \in N^s$.

[9] In the south, a similar project, the *Blue Stream* pipeline through the Black Sea to Turkey, started operations in 2002 under a long–term agreement with Turkish Botag. It substitutes for pipelines running through Ukraine, Moldavia, Romania and Bulgaria, were conflicts have been similar to those on the East–West routes.

[10] All expressions for revenues and cost are understood as expected annualized figures over the lifetime of the investment.

Originally, the Shapley solution was obtained from axiomatic reasoning, leaving open the question which particular (non–cooperative) bargaining process would be able to achieve the efficient outcome and the Shapley sharing.[11] Meanwhile, the theoretical literature has proposed a number of non–cooperative foundations of the Shapley value.[12] Of these, the model of Stole & Zwiebel (1996a) and Stole & Zwiebel (1996b) appears to fit real world bargaining in the gas market particularly well. They look at bilateral negotiations with a central player without whom nothing can be achieved, assuming that all agreements can be renegotiated before any plans are executed. Only the Shapley–sharing of profits is renegotiation–proof. In the Eurasian gas market, Russia is a central player in the sense of Stole and Zwiebel and negotiations with transit countries are usually bilateral. As a rule, there are many rounds of negotiations, resulting in letters of intent, preliminary agreements etc., which will be renegotiated several times before final deals are made.

In the first stage the access structure is determined through investment and contracting. Since we do not assume efficient bargaining at this stage, we cannot take it for granted that the Grand coalition will form. Instead, we have to allow for arbitrary coalition structures, which correspond to different partitions of $N$. For later reference let $N^P$ denote the set of all partitions, and $P \in N^P$ be a possible coalition structure. Different to most of the literature in cooperative game theory we do not assume that members of a coalition 'unite' or 'merge' in any sense. They merely have the opportunity to cooperate and we explicitly analyze which form of cooperation is best for them.[13] Members of a coalition $M \in P$ can coordinate in two dimensions.[14] They may change the access regime by modifying the rights to grant or deny access to capacities in future bargaining, and they may coordinate their investments which determine what capacities will be physically available for production. In doing so, they will take the strategies of other coalitions as given, and rationally anticipate how investment and access regime effect bargaining over rents. Hence, for any given coalition structure $P$, we look for a subgame perfect Nash–equilibrium, where the expected payoffs in the rent–division subgame are given by the Shapley value. It is convenient to address the issues of access rights and investments in turns.

[11] As Shapley (1953) has shown, it is the only rule for sharing the profits from multilateral cooperation which fulfills some reasonable criteria which are (i) that players who do not contribute anything to any of the possible coalitions should receive nothing, (ii) payoffs should only depend on the players role in the game not an assumed differences in personal bargaining power etc. and (iii) we can take expected payoffs under uncertainty (which makes sense if players are risk neutral). Myerson (1980) added further appeal to the Shapley value by showing that it is the unique rule for dividing the gains from cooperation which obeys simple rules of fairness and balanced contributions.

[12] Gul (1989) analyzes sequential trade. At each round the players match randomly in pairs. Those who sell their assets leave the game. The value of the assets which a player accumulates equals the value of a coalition of the players whose initial endowments he obtained through trade. When the gains from trade are equally split, the expected profits are given by Shapley value. Inderst & Wey (2001) analyze simultaneous negotiations over contingent contracts. Each member of the higher level in a vertical chain (producer) bargains with every member of the lower level (retailer) simultaneously. Gains from trade are shared equally for every possible contingency, notably, the possibility that other negotiations may fail.

[13] As a consequence, coalitions can never be harmful to its members. The worst to happen is that they cannot improve over what they can achieve individually.

[14] Here $M = \{..i..j..\}$ denotes the set of players forming a coalition. Hence, $M \subseteq N$ and $M \in P = \{K_1..M..K_n\}$.

**Access Regime**

Let the previously defined value function $v$, characterize the initial access regime corresponding to the de facto control over links in the absence of agreements. Then a contract $A$ changing the access regime can be represented by a new value function $vA(S) = v(A(S))$. Such an agreement among the players of $M$ can only be beneficial if it increases $\phi_M$. Since, for given capacities, the total value of the Grand coalition does not change, i.e. $\phi_N(vA) = v(N)$, this is equivalent to harming the players which are not in the coalition, i.e. $\phi_{N/M}(vA) < \phi_{N/M}(v)$. With physical capacities already fixed, coalitions do not form to increase 'the cake', they only form to increase bargaining power in the fight over the division of cake.

Following Segal (2003) we distinguish between inclusive and exclusive contracts, and collusion, to characterize cooperation. A bilateral inclusive contract $I_i^j$ grants player $i$ access to $j$'s resources without preventing $j$ from using them on his own. It changes the value functions according to: $vI_i^j(S) = v(S \cup j)$ if $i \in S$; and $v(S)$ otherwise. The inclusive contract makes a difference only for subsets $S$ including $i$ but not including $j$. Hence, the effect of the inclusive contract on the expected share of a third player $k \notin M$ is given by $\sum_{S:i\in S, j\notin S} \alpha_S \Delta_{kj}^2 v(S)$, where $\Delta_{kj}^2 v(S) = v(S \cup k \cup j) + v(S \backslash k \backslash j) - v(S \backslash k \cup j) - v(S \backslash j \cup k) = \Delta_{jk}^2 v(S)$ denotes the impact of $j$'s inclusion on the marginal contribution of $k$. A sufficient condition for an inclusive contract to impose a negative externality on a third player $k$ is that the included player $j$ is substitutable to $k$ in the presence of $i$, i.e. $\Delta_{kj}^2 v(S \cup i) \leq 0, \ \forall S$. Note, that the contract $I_i^j$ weakens player $j$'s bargaining power, because his marginal contributions to all subsets $S : i \in S, j \notin S$ are reduced to zero. Hence such a contract is only feasible, if (i) player $j$ can commit to grant $i$ access to his resources, and (ii) player $i$ can either compensate $j$ for his loss in bargaining power up–front or commit to compensate later.

An exclusive contract $E_i^j$ gives player $i$ the right to exclude player $j$. It amounts to: $vE_i^j(S) = v(S)$ if $i \in S$; and $v(S \backslash j)$ otherwise. The exclusive contract makes a difference only for subsets $S$ which include $j$ but not include $i$. A sufficient condition is, that for a third player $k$ to suffer from the exclusion of $j$, is that he is complementary to $j$ in the absence of $i$, i.e. if $\Delta_{kj}^2 v(S \backslash i) \geq 0, \quad \forall S$. Note, that the contract weakens player $j$'s bargaining power, because his marginal contributions to all subsets $S : i \notin S, j \in S$ are reduced to zero. Hence such a contract is only feasible, if (i) player $j$ can commit to grant $i$ veto over the use of his resources, and (ii) player $i$ can either compensate $j$ for his loss in bargaining power up–front or commit to compensate later.

As is discussed in more detail in Segal (2003) full collusion in which one player, say $i$ acts as a proxy player for the others, which become dummies can be implemented by a combination of the two contracts. The inclusive contract gives the proxy player access to the resources of the other players. The exclusive contract prevents the rest from using these resources on their own, hence, $vC_i^j(S) = v(S \cup j)$ if $i \in S$; $v(S \backslash j)$ otherwise. A sufficient condition for the union $C_i^j$ to be detrimental for a third player $k$ is $\Delta_{ijk}^3 v(S) \leq 0$. In this case $k$ decreases the complementarity between the colluding players $i$ and $j$. Note, that $\Delta_{ijk}^3 v(S)$ is independent of the ordering of players. As the Shapley value is symmetric it does not matter which player is made the proxy and which the dummy. Hence, the contract requires (i) that $j$ (or $i$) is able to commit to fully hand over control over his resources and (ii) that $i$ ($j$) can commit to compensate $j$ ($i$) for his complete loss of bargaining power, or to pay up–front. We summarize these results in proposition 1:

**Proposition 1** *With capacities fixed, $i, j \in M$:*

1. *Contracts $A_i^j, A \in \{I, E, C\}$ are only feasible if $i$ can compensate $j$ up–front or commit to make payments in the future, moreover we have:*
2. *$I_i^j$ is beneficial and feasible if:*
   $\Delta_{I_i^j}(k) = \sum_{S:i\in S, j\notin S} \alpha_S \Delta^2_{kj} v(S) < 0$, $\forall k \notin M$, *and $j$ can commit to grant $i$ access.*
3. *$E_i^j$ is beneficial and feasible if:*
   $\Delta_{E_i^j}(k) = \sum_{S:i\notin S, j\in S} \alpha_S \Delta^2_{kj} v(S) > 0$, $\forall k \notin M$, *and $j$ can commit to grant $i$ veto.*
4. *$C_i^j$ is beneficial and feasible if:*
   $\Delta_{C_i^j}(k) = \sum_{S:i\in S, j\notin S} \alpha_S \Delta^2_{ijk} v(S) < 0$, $\forall k \notin M$, *and $j$ can commit to give $i$ control.*

Where $\Delta_{I_i^j}(k) = \phi_k(I_i^j v) - \phi_k(v)$. It is straightforward to extend the proposition to multilateral contracts.

### Investment

As is clear from the definition of $v(S)$ in expression (1) the characteristic function depends on the installed capacities. To make this explicit we may write $v_{[l]}$, where $l$ denotes the set of capacities along the various tracks. Given a coalition structure $P$, an access regime $A_P$ we have to distinguish between links which are under complete control of a coalition $i$ and other links. As to links completely under its control a coalition will cooperatively determine investment. However, a player or coalition may also contemplate investment into a link which is not completely under its control and therefore involves other players or coalitions. While such investment suffers from the 'hold up' problem, it may still be sufficiently more efficient to warrant consideration. Since larger capacities increase a player's bargaining power at the production stage, no one has an incentive to prevent others from investing on their own expenses into resources under his effective control. We assume that players $i$ and $j$ are able to ensure technical coordination to establish a complete link at maximum capacity, even if they belong to different coalitions and determine the level of investment funds non–cooperatively. With non–cooperative funding but cooperative technical implementation, the total capacity on link $l^n$ will be given as $l^n = l_i^n + l_j^n$. In other words capacities along the same track are perfect substitutes.[15]

### Equilibrium

Consider a coalition structure $P$ at the first stage of the game. By entering into a contract $A_i^j$, the members of a coalition $M$ change the access regime from $vA_{P\setminus M}$ to $vA_i^j(A_{P\setminus M})$, where $A_{P\setminus M}$

[15] Alternatively, one could assume that each player invests only on his territorial section of the link. In this case capacities would be perfect complements, $l^n = \min[l_i^n, l_j^n]$. However, this would require, that (out of equilibrium) players spend huge sums over several years on pipeline projects which have no connection on others players' territory and are therefore completely worthless.

denotes the composition of contracts selected by the other coalitions. The different coalitions will non–cooperatively select contracts and investment which they consider as optimal for them. The expected profit of a coalition $M \in P$ given the strategies of the other players is:

$$\Pi_M(\{l_M, A_M\}, \{l_{P\backslash M}, A_{P\backslash M}\}) = \phi_M(\, v_{[l_M + \sum_{K\in P\backslash M} l_K]} A_M(A_{P\backslash M})\,) - c(l_M)$$

where $A_M$ denotes the composition of contracts selected by the members of coalition $M$, and $c(l_M)$ its annualized investment cost. Denote the optimal strategy of coalition $M$ given the strategies of coalitions $P\backslash M$ as $\{A^*_M, l^*_M\}$, then the subgame perfect Nash–equilibrium is a pair $\{A^*_P, l^*_P\}$, where $l^*_P = \sum_{M\in P} l^*_M$ and $A^*_P$ is the composite of $A^*_M$, $\forall M \in P$. In principal, there may be multiple equilibria.

Since the profit of a coalition depends on the strategies of other coalitions we have to account for the possible externalities across coalitions and extend the payoff function to depend on the entire coalition structure, the partition.[16] Fortunately, it turns out that the Nash equilibria for the different partitions are unique and have a simple structure for realistic values of investment cost. As a result, there will be no 'externalities' in equilibrium and we can represent the game at the investment stage again in simple value function form. To determine how the members of the coalitions share their profit at the investment stage, we follow Owen's (1977) proposal to define a new game among the members: $w : M^s \rightarrow R$. The characteristic function $w$ is derived from the original game according to: $w(S) = \Pi^{P_S}_S(A^*_{P_S}, l^*_{P_S})$, $S \in M^s$ where $P_S$ denotes the partition which is obtained from $P$ by replacing $\{..M..\}$ with $\{..S, \{p_1\}, \{p_2\}..\{p_n\}..\}$, with $\{p_1, p_2..p_n\} = M\backslash S$, that is if the players $M\backslash S$ would act 'as singletons'.[17] Hence, the payoff of a sub–coalition $S$ of a coalition $M$ reflects S's power in the overall game. The so called Owen value $\psi : M \rightarrow R$ is simply the Shapley value of this modified game: $\psi = \phi(w)$. In difference to Owen's original model, the various coalitions $S \in M^s$ will differ in their investment, hence, result in different payoffs for the Grand coalition in the final game.

# 4 Qualitative Analysis

In this section we use the theoretical framework to provide for a qualitative analysis of strategic investment in the Eurasian gas system. We consider four independent players Russia, Poland, Belorussia, and Ukraine denoted $R$,$P$,$B$, and $U$, respectively. The situation we have in mind is the state of the system in the early nineties, that is before Yamal had been built. As to the ability of the players to commit, we look at two different cases. In the first we assume that only Ukraine lacks this ability. This captures reasonable expectations in the early nineties, when Russia and Belorussia apparently found a long–term solution for the transit problem. However, these agreements unravelled later on and in the second variant we assume that Belorussia, as the Ukraine,

[16] For an axiomatic approach to the analysis of payoffs and coalition formation in games with externalities see Maskin (2003), for an extensive form bargaining approach see Ray & Vohra (1999).

[17] In Owen (1977) $P_S$ is given by $\{..S..\}$, i.e. as if the players $M\backslash S$ would 'disappear'. Hart & Kurz (1983) show, that if the payoff of the Grand coalition is constant, both approaches are equivalent and yield the same result as if $P_S = \{..S, M\backslash S..\}$, i.e. the players $M\backslash S$ would 'stay together'. Whether this equivalence, holds true with investment and non–constant payoffs is an open question.

can neither make long–term commitments nor pay up–front. Investment possibilities exist along three tracks: Nort-Trans-Gas, Yamal, and Southern System through Ukraine, denoted $(n, y, s)$. As should be clear from the description in section 2, the smallest coalition for $y$ is $\{R, P, B\}$, $s$ requires at least $\{R, U\}$, and $n$ needs only $\{R\}$.

We will describe the features of the various investment options in more detail in the next section. Here, we assume that marginal investment cost for new capacities are piecewise constant. The existing capacities in Ukraine, denoted $s_o$ are available at zero investment cost. Upgrading the system up to a capacity of $\bar{s}$ has lowest marginal investment cost $c_s$. To simplify the exposition we ignore the possibility to invest more than $\bar{s}$ in the south. This does not effect our results. The construction of new pipelines along the Yamal–track through Poland is more expensive, but still cheaper than going offshore (North–Trans–Gas), i.e: $c_s < c_y < c_n$. Further, we assume that marginal operating cost are the same for all tracks. Hence, capacities on the different tracks are perfect substitutes, at the production stage.[18] This allows us to lump all capacities together and evaluate the marginal impact of capacity on operating profits as: $\max[\pi'(n + y + s + s_o), 0]$, where $\pi$ is defined in (1). Note that $\pi'$ cannot be negative, as it is always possible to leave capacity idle at the production stage.

A contract granting Russia access to capacities in Poland and Belorussia ($I_R^{PB}$) is beneficial for $y > 0$, because Poland and Belorussia are substitutable to Ukraine in the presence of Russia. A contract giving Ukraine the right to exclude Poland $E_U^P$ would increase the bargaining power of the two for $y > 0$, because Russia is complementary to both of them. Obviously $I_R^{PB}$ and $E_U^P$ are mutually exclusive. This raises the question, which agreements the various possible coalitions would choose at the contracting stage. Furthermore, the gains from entering different possible coalitions may, in principle, depend on the capacities. As it turns out, however, by assuming that Ukraine is prone to recontracting and cannot pay up–front we can effectively rule out all contracts except $I_R^{PB}$ by applying proposition 1:

**Proposition 2** *For $P_{\{RPB\}} = \{\{R, P, B\}, \{U\}\}$ the access regime is equivalent to $vI_R^{PB}$. For all other partitions the access regime is $v$, hence the same as for $P_\emptyset = \{\{R\}, \{P\}, \{B\}, \{U\}\}$.*

Proof: (sketch) It is easy to see that contracts involving Ukraine are not feasible. Ukraine cannot afford contracts of the format $A_U^i$ and cannot make the commitments required by $A_i^U$. Hence, it is sufficient to consider coalition structures in which $U$ is a singleton, i.e. $P = \{.., \{U\}\}$. With 4 players there are $4! = 24$ possible orderings for the calculation of the Shapley value at the bargaining stage. Note further that $P$ and $B$ are symmetric in this game.

We start by analyzing the impact of contracts and then we turn to coalition structures. Consider the contract $I_R^B$. By proposition 1(2) it is feasible, provided that $R$ and $B$ belong to the same coalition at the investment stage. It will weaken $U$ at the recontracting stage because for all coalitions including $R$ and $P$, the included player $B$ is substitutable to the outside player $U$. As a result $I_R^B$ decreases $U$'s marginal contribution in all orderings for which both, $R$ and $P$, precede $U$

[18]This assumptions will be dropped in the numerical part. At the rent–division stage only operating cost matter, and with respect to these Yamal is actually slightly cheaper than the southern track.

and $U$ precedes $B$. These are 2 out of possible 24, both assessing the marginal contribution of $U$ to $\{R, P\}$. Hence, the impact of $I_R^B$ on Ukraine is given as:

$$\begin{aligned} \Delta_{I_R^B}(U) &= (1/12)\Delta^2_{UB}v(RP) \\ &= \frac{1}{12}\left[(v(RPUB) - v(RPB)) - (v(RPU) - v(RP))\right] < 0 \end{aligned}$$

The same contract will strengthen $P$'s bargaining power because $P$ is complementary to $B$ in the presence of $R$. The relevant orderings are those for which $R$ precedes $P$ which is followed by $B$. Hence:

$$\begin{aligned} \Delta_{I_R^B}(P) &= (1/12)\Delta^2_{PB}v(R) + (1/12)\Delta^2_{PB}v(RU) \\ &= \frac{1}{12}(v(RUPB) - v(RU)) + \frac{1}{12}(v(RPB) - v(R)) > 0 \end{aligned}$$

The last expression is obtained using the fact that at the recontracting stage the inclusion of only either $B$ or $P$ to a coalition does not change its value, i.e. $v(\{R, P\}) = v(\{R\})$, $v(\{R, U, P\}) = v(\{R, U\})$ etc.

Now we turn again to coalition structures. First consider $P_{\{RPB\}} = \{\{R, P, B\}, \{U\}\}$. In this case $U$ is the only outside player. The members of $\{R, P, B\}$ will not sign exclusive contract, as this would benefit $U$ by proposition 1(3). We have established already, that $I_R^B$ is beneficial, because it hurts $U$. But multilateral inclusion $I_R^{PB}v = I_R^P(I_R^B v)$ is even better than bilateral inclusion because it decreases $U$'s marginal contribution also with respect to the coalition $\{R, B\}$. Moreover, by similar reasoning it can be shown that $I_R^{BP}$, dominates all other multilateral inclusive contracts among the three players. This proves the first claim of the proposition.

It remains to be shown that all partitions involving a coalition of two players have nothing to gain from changing the access regime. Consider $P_{\{RB\}} = \{\{R, B\}, \{P\}, \{U\}\}$ and again bilateral inclusive contract $I_R^B$. The contract is harmful for the coalition $\{R, B\}$ because the total impact on all outside players is positive:

$$\begin{aligned} \Delta_{I_R^B}(U) + \Delta_{I_R^B}(P) &= (1/12)\Delta^2_{UB}v(RP) + (1/12)\Delta^2_{PB}v(R) + (1/12)\Delta^2_{PB}v(RU) \\ &= (1/6)\Delta_B v(RPU) > 0 \qquad (2) \end{aligned}$$

where the last line is obtained, by rewriting all expressions in terms of marginal contributions of $B$ (recall that $\Delta^2_{UB} = \Delta^2_{BU}$) and simplifying the result.

Analog reasoning for $P_{RP}$ and $P_{PB}$ shows that other bilateral coalitions can also not improve upon the original access regime $v$. Hence coalition structures with bilateral coalitions have the same access structure as $P_\emptyset$. ■

Note that proposition 2 does not depend on the capacities. In our special context we can first determine the optimal access regime and then analyze the incentives for investment. Furthermore, it gives a lot of mileage for proving that at the investment stage the coalition involving Russia is not effected by externalities from other coalitions, which is a pre-condition for defining a value function for the investment game. If there are any externalities these have to work through investment, not through the access regime.

Table 1: Access Regime and Rent Sharing in Terms of Value Function

| | | |
|---|---|---|
| $\phi_R(v)$ | : | $+\frac{5}{12}v(\{R\}) + \frac{1}{12}v(\{R,P,B\}) + \frac{1}{4}v(\{R,U\}) + \frac{1}{4}v(\{R,P,U,B\})$ |
| $\phi_P(v)$ | : | $-\frac{1}{12}v(\{R\}) + \frac{1}{12}v(\{R,P,B\}) - \frac{1}{4}v(\{R,U\}) + \frac{1}{4}v(\{R,P,B,U\})$ |
| $\phi_B(v)$ | : | $-\frac{1}{12}v(\{R\}) + \frac{1}{12}v(\{R,P,B\}) - \frac{1}{4}v(\{R,U\}) + \frac{1}{4}v(\{R,P,B,U\})$ |
| $\phi_U(v)$ | : | $-\frac{1}{4}v(\{R\}) - \frac{1}{4}v(\{R,P,B\}) + \frac{1}{4}v(\{R,U\}) + \frac{1}{4}v(\{R,P,B,U\})$ |
| $\phi_{RPB}(vI_R^{PB})$ | : | $+\frac{1}{2}v(\{R,P,B\}) + \frac{1}{2}v(\{R,P,B,U\})$ |
| $\phi_U(vI_R^{PB})$ | : | $-\frac{1}{2}v(\{R,P,B\}) + \frac{1}{2}v(\{R,P,B,U\})$ |
| $\phi_{RPBU}$ | : | $v(\{R,P,B,U\})$ |

Table 1 describes the effect of changing the access regime for given capacities. It gives the Shapley values at the rent sharing stage for the various players for different coalition structures and the corresponding access regimes.[19] The first four rows refer to $P_\emptyset$, the case in which the four players act independently and the access regime is given by $v$. The next two rows refer to $P_{\{RPB\}}$ with Russia, Poland and Belorussia forming a coalition in which Poland and Belorussia commit to grant Russia access to their transport pipelines ($vI_R^{PB}$).

Using the definition of the value function (1) we can obtain the shares of rent in terms of operating profits and capacities from table 1 by substituting $\pi(n+y+s+s_o)$ for $v(\{R,P,B,U\})$, $\pi(n+y)$ for $v(\{R,P,B\})$ etc. For a benchmark case, assume that all players could commit not to recontract, form the Grand coalition at the investment stage and invest to maximize industry profits, without any strategic considerations. They would solve:

$$\max_{n,y,s} \Pi_{RPBU} = \pi(n+y+s+s_o) - c_n n - c_y y - c_s s; \quad s.t.\ s \leq \bar{s} - s_o$$

For further reference denote the solution $\{n^*, y^*, s^*\}$.

In order to streamline exposition we assume that in the initial situation, with installed capacity $s_o$, some investment into upgrading the Ukrainian system (the cheapest option) is warranted $c_s < \pi'(s_o)$. Yamal is the second best option and will always dominate investment on $n$, hence, we may have two possible outcomes: $\{n^* = 0, y^* = 0, s^* \leq \bar{s} - s_o\}$ or $\{n^* = 0, y^* > 0, s^* = \bar{s} - s_o\}$. First order condition for an interior solution are $\pi'(s^* + s_o) = c_s$ and $\pi'(\bar{s} + y^*) = c_y$, respectively.

Now we consider the coalition structure $P_{\{RPB\}}$. Russia, Poland and Belorussia maximize

$$\Pi_{RPB} = \frac{1}{2}\pi(n+y+s+s_o) + \frac{1}{2}\pi(n+y) - c_n n_{RPB} - c_y y_{RPB} - c_s s_{RPB}$$

and Ukraine maximizes

$$\Pi_U = \frac{1}{2}\pi(n+y+s+s_o) - \frac{1}{2}\pi(n+y) - c_n n_U - c_y y_U - c_s s_U,$$

[19] Note that $v(\{P\}) = v(\{B\}) = v(\{U\}) = v(\{P,U\}) = v(\{B,U\}) = v(\{P,B\}) = v(\{P,U,B\}) = 0$, as these coalition cannot establish a complete link.

where $l_i$, $l \in \{n, y, s\}$, $i \in \{RPB, U\}$ denotes $i$'s investment into link $l$ and $l = \sum l_i$ is the total capacity. The expressions are obtained from the expected rent given in the fifth and sixth row of table (1). Since $\pi'(n + y + s + s_o) < \pi'(n + y)$, Ukraine would never invest on $y$ or $n$. However, provided that $\pi'(s_o)/2 < c_s$ it would not even invest into the upgrade of the southern system, and the same holds true for the coalition. Investment is discouraged, because both sides anticipate, that returns have to be shared with the other side at the recontracting stage, the classic hold–up problem. The incentives to invest in $y$, however, are much increased. For the coalition the marginal returns are given by $\pi'(y^{RPB})/2 + \max[\pi'(y^{RPB} + s_o), 0]/2$. Not only that marginal returns on investment on Yamal receive full weight, the competing capacities in the south are strongly discounted in the evaluation. This increases the incentives to invest well above what would prevail in the first best situation. Depending on the relative strength of these effects and on capacity cost there will be (i) underinvestment, (ii) distorted investment in the sense that more costly options are chosen, (iii) overinvestment, in the sense that total capacity is larger than under full commitment, and even (iv) excess capacity which will be left idle at the production stage.

**Proposition 3** *If $c_y$ and $c_s$ are high enough, there will be underinvestment. If $c_y$ and $c_s$ are low enough, there will be overcapacity and even unused excess capacity.*

Proof: Note that $y^{RPB}$ is continuous in $c_y$. Hence it is sufficient to prove underinvestment for large enough $c_y$ and excess capacity for low enough $c_y$. Underinvestment: If $c_y > \pi'(s_o)/2 + \pi'(0)/2$ then $y^{RPB} = y^* = 0$, if at the same time $c_s > \pi'(\bar{s})/2$ then $0 = s^{RPB} < s^*$. Excess capacity: We have to show that $\exists c_y$ so that $\pi'(s_o + y^{RPB}) < 0$. Assume $c_y \to c_s$ and define $\hat{y}(c_s)$ by $2c_s = \pi'(\hat{y})$. Obviously $\hat{y} \leq y^{RPB}$, hence $\pi'(\hat{y}) > \pi'(s_o + \hat{y}) \geq \pi'(s_o + y^{RPB})$. Evaluated at $c_s = 0$ we obtain $0 = \pi'(\hat{y}(0)) > \pi'(s_o + \hat{y}(0)) > \pi'(s_o + y^{RPB})$. ■

Now we turn to the second case and assume that Belorussia, like Ukraine, is prone to recontract. This corresponds to the coalition structure $P = \{\{R, P\}, \{B\}, \{U\}\}$. Anticipating bargaining over rents with Belorussia, Russia and Poland would no longer benefit from a contract granting access to capacities at Yamal (proposition 2). Hence, their expected rents are given by $\phi_R(v) + \phi_P(v)$ and investment is chosen to maximize:

$$\Pi_{\{RP\}} = \frac{1}{3}\pi(n) + \frac{1}{6}\pi(n + y) + \frac{1}{2}\pi(n + y + s + s_o) - c_n n_{RP} - c_y y_{RP} - c_s s_{RP}.$$

Belorussia maximizes

$$\Pi_{\{B\}} = -\frac{1}{12}\pi(n) + \frac{1}{12}\pi(n + y) - \frac{1}{4}\pi(n + s + s_o) + \frac{1}{4}\pi(n + y + s + s_o) - c_n n_B - c_y y_B - c_s s_B.$$

Obviously, Belorussia would neither invest in $s$ nor in $n$. Its incentives to invest into $y$ are ambivalent. On the one hand the coefficients of the terms which take $y$ into account (1/12 and 1/4) sum up to only less than half. In this sense returns to investment are sharply discounted. On the other hand, some weight (1/12) is put on a situation in which marginal returns are evaluated well above social returns because the capacities $s$ are ignored. The coalition's incentives to invest in Yamal are somewhat stronger (with coefficients 1/6 and 1/2) but still weaker than in the previous case. Incentive to invest in North–Trans–Gas, in contrast, are unambiguously enhanced. Not only that full weight is given to its marginal impact on operating profits. Marginal revenues are also evaluated giving little weight to the capacities $y$ and $s$. This implies that equilibrium investment may be distorted even further towards high–cost off–shore links if Belorussia's ability to enter long–term agreements is in doubt.

# 5 Quantitative Analysis

## Assumptions

The payoff which a particular coalition can achieve depends on demand for Russian natural gas, on production cost and on the cost of transport along the routes which are available for this coalition. Demand and production cost are assumed to be independent of transport routes to the west. This will be true to the extend that the capacity of pipelines running from north to south in Germany are large enough to avoid large discrepancies in prices between the different regions. On the supply side, it requires low variable transportation cost between Torzhok and the Ukrainian border or the possibility to substitute Siberian gas for gas from Turkmenistan.

The demand for Russian natural gas depends on preferences for natural gas, the prices of substitutes such as oil and gas from competitors, preferences for diversifying energy supply, the cost of transporting gas within Western Europe etc. Unfortunately, data on gas prices and consumption in Western Europe are too poor to allow an econometric estimation of this function. The bulk of the deliveries is under a small number of long–term contracts, the details of which are not made public. Available data on gas prices largely reflect oil–price movements. They are of little relevance for the buyers tied up in these agreements. Moreover, many of the important structural determinants of demand for Russian gas, such as environmental concerns, preferences for diversity of supplies, turbine technology etc., are changing fast. For simplicity, we take a linear specification of the demand function and make 'plausible assumptions' for the parameters. An intercept of 145 \$/tcm and slope of $-0.3$ for the inverse demand yield a price slightly below current levels at current export levels which would be optimal, given our assumptions on production and transport cost.

The production costs of Russian gas tend to increase as production from old low cost fields declines and new, more expensive fields have to be developed. Since this happens faster as production levels increase, annualized marginal production cost increase.[20] Production depends to a substantial extent on sunk investment (exploration, wells, pipelines) in old fields, hence, there is room for argument what exactly should be counted as cost. For simplicity we assume a linear marginal cost schedule $mc_o(x) = 11+0.4x$ for a quantity $x$ at the Russian export node. The intercept $mc_o(0) = 11$ \$/tcm reflects marginal production cost from old fields such as Urengoy or Zapolyarnoye. For the current export level we obtain $mc_o(90) = 47$ \$/tcm which corresponds well to estimated development cost for Yamal and the current price for imports from Turkmenistan.[21]

The total cost of transporting gas can be decomposed into capacity cost and operating cost, which

[20] For the purpose of this paper production cost include transport from the field to the major link connecting Torzhok with eastern Ukraine.

[21] For long-term perspectives of Russian gas production and its cost see Stern (1995) and Observatoire Mediterraneen de L'Energie (2002).

Table 2: Transport Links for Russian Gas

| | capacity[a] | investment[b] | length[c] | capacity cost[d] | marginal cost[e] at 0/90 bcm/a |
|---|---|---|---|---|---|
| | [bcm/a] | [bn$] | [km] | [$/tcm/100km] | [$/tcm] |
| Southern track, existing | 70[f] | sunk | 2000 | sunk | 14 / 54 |
| (Russia, Ukraine) | A system of parallel pipelines, gas storages, compressors, mostly depreciated and in poor state of repair. | | | | |
| Southern track, upgrade | 15 | 0.75 | 2000 | 0.39 | 22 / 59 |
| (Russia, Ukraine) | Mostly repairs and replacement of compressor power. | | | | |
| Yamal* | 28 | 3.4 | 1600 | 1.35 | 35 / 73 |
| (Russia, Poland, Belorussia) | Frankfurt/O — Torzhok. As the pipeline is already finished, this is an ex–ante perspective of the project. | | | | |
| North Trans Gas* | 30 | 4.2 | 1600 | 1.80 | 50 / 89 |
| (Russia) | Greifswald (Germany) — Vyborg (Russia) 1200 km offshore, 400 km onshore to Torzhok. Originally planned for 18 bcm/a. | | | | |

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

[a]As existing or typically planned.

[b]Estimated investment cost obtained from various sources.

[c]From point of delivery in Western Europe to the main Russian export node of the grid.

[d]Annualized investment cost with an expected lifetime of 25 years and interest rate for real investment of 15% (excluding interest during construction).

[e]Total marginal cost of gas supply at the border of Western Europe: $mc(0, y)$ / $mc(90, y)$, with $y$ and $c$ as given in the previous two columns and $m = 0.1$ $/tcm/100km for onshore pipelines ( $m = 0.2$ for offshore pipes), and $g = 0.0025$ /100km ($g = 0.005$ /100km for the old system in Ukraine and for offshore pipelines).

[f]Only capacity used for export to Western Europe.

consist of management and maintenance cost and energy cost.

The cost of providing transport capacity with pipelines is roughly proportional to distance. In principle, there are several types of economics of scale. Some are related to the pipeline itself, others are gains obtained from laying pipelines along the same track. Capacity economics of scale appears to fade out at a capacity of 20 bcm/year, though this effect is somewhat weaker with offshore pipelines than with onshore pipes.[22] For simplicity we ignore scale effects and assume proportional cost in the following calculation. As we obtain rather large additional investments this will be of little consequence. There are several reasons to install additional pipes parallel to existing ones (track economics of scale). To account for these we use specific cost estimations for the different routes and inflate cost of entirely new pipelines by 15%. As we express all figures on an annual basis, we obtain pipeline specific, annualized cost of capacity from the initial investment cost $I$ as $c = r \cdot I/(1 - (1 + r)^{-T})$, where $T$ denotes the expected lifetime of the facilities and $r$ the interest rate for real investment.

The costs of management and maintenance $m$ depend on the pipeline (old, offshore) but otherwise are assumed to be proportional in distance and quantity. For a given distance a certain fraction of gas $g$ is used for pressurizing. As $g$ is approximately constant along the track, we can calculate the marginal cost of supplying gas according to: $mc(x, y) = mc_0(x)\, e^{g \cdot y} + (e^{g \cdot y} - 1)(c + m)/g$, where

[22]For further information see Oil, Gas and Coal Supply Outlook (1994) and International Energy Agency (1994).

$y$ denotes the distance from the source, and $mc_0$ the marginal cost of gas at the source, i.e. the production cost.[23] Note, that the parameters $m$, $c$, and $g$ refer to the marginal link, while $x$ refers to the aggregate quantity.

As is shown in the last column of table 2 marginal supply costs are lowest for the existing capacities along the Southern track and highest for the planned offshore pipeline through the Baltic Sea. Marginal costs of supplying Russian gas to Western Europe increase because production costs increase as old fields have to be supplemented by new more expensive fields and transport costs increase as old established connections have to be modernized and supplemented by more expensive new connections.

## Results

Based on these assumptions on functional forms and parameters we can solve numerically for the equilibria of the various coalition structures. It turns out that in equilibrium there would be no investment in links without assured access. In other words, investment in Yamal requires the coalition of all three participants ($P_{RPB}$). If this coalition fails to form ($P_{RP}$, $P_{RP}$ ..), there will be only investment in North-Trans-Gas.[24] Investment into unsecured links occurs only out of equilibrium. For example, if $R$ did not invest in NTG, $P$ and $B$ would to invest small amounts into Yamal even if there were not in a coalition with Russia and access would not be assured ($P_{BP}$, $P_{\emptyset}$). Similarly, Ukraine would invest into upgrading the old system on its own, if there were no investment on Yamal or NTG. However, given the strong strategic incentive to invest in Yamal, respectively NTG, these constellations do not constitute equilibria. Table 3 gives the results in terms of aggregate figures and table 4 in terms of the shares of the various players.

As in the previous section we start with the reference case, in which all players could commit and optimize investment to maximize industry profits (coalition structure $P_{RPBU}$). In this case investment would have been: $\{n^*, y^*, s^*\} = \{0, 0, 15\}$, i.e. investment is concentrated on the upgrading of the old system in the south from 70 bcm/a to 85 bcm/a. This capacity would have been fully used, yielding an annual operating profit (rent) of \$ 5.789 bn and a net profit of \$ 5.673 bn. However, this outcome is not feasible given our assumption about Ukraine.

For the coalition of Russia, Poland and Belorussia ($P_{RPB}$) we obtain a different picture. Rather than using the cheapest option in the south, new investment is strategically directed into a large Yamal project with 60 bcm/a capacity. Together with the already existing 70 bcm/a in the South, total capacity reaches 130 bcm/a of which a staggering 40 bcm/a are subsequently left idle. Sales of 90 bcm/a generate an operating profit of \$ 5.826 bn, which is reduced by high investment cost to a net profit of only \$ 4.530 bn. In order to calculate how Russia, Belorussia and Poland share the joint profit we have to look at the game in which every player acts on its own ($P_{\emptyset}$). In equilibrium

[23] The formula is obtained by asking how much the cost increase along $\Delta y$: $mc(y + \Delta y) - mc(y) = [(c + m) + g \cdot mc(y)] \cdot \Delta y$. Dividing by $\Delta y$ and taking the limit and solving the differentiation equation yields the expression in the text.

[24] This implies that equilibrium investment does not depend on the formation of bilateral coalitions. Hence, in equilibrium there are no externalities across coalitions through investment. Together with proposition 2 we can rule out externalities alltogether and calculate the Owen value for the game at the investment stage.

Table 3: Equilibrium Capacities, Quantities, Aggregate Profits

| | investment $\{n, y, s\}$ bcm/a | capacity [quantity used] bcm/a | Price $/tcm | operating profit (rent) $ mln/a | investment cost $ mln/a | net profit $ mln/a |
|---|---|---|---|---|---|---|
| First best | $\{0, 0, 15\}$ | 85 [85] | 119 | 5789 | 116 | 5673 |
| Coalition: $R, P, B$ | $\{0, 60, 0\}$ | 130 [90] | 118 | 5826 | 1296 | 4530 |
| No Cooperation | $\{54, 0, 0\}$ | 124 [88] | 118 | 5755 | 1345 | 4410 |

Table 4: Shares of Net–Profits and Rents

| variant | Russia (rent) $ mln/a | Russia profit $ mln/a | Poland profit $ mln/a | Belorussia profit $ mln/a | Ukraine rent $ mln/a |
|---|---|---|---|---|---|
| Grand Coalition | | 4847 | 27 | 27 | 773 |
| First best investment but recontracting | (2895) | 2779 | 0 | 0 | 2895 |
| Coalition: $R, P, B$ | | 4073 | 106 | 106 | 245 |
| No Cooperation | (5312) | 3967 | 0 | 0 | 443 |

there is no investment in Yamal but a very large investment of 54 bcm/a in North–Trans–Gas resulting in a total capacity of 124 bcm/a at the production stage.

The figures for profit sharing explain why countervailing power is so important in this transmission system. If Russia had naively followed the first best investment strategy, paying for the upgrade in Ukraine up–front and then had been forced to bargain over rents, its bargaining power would have been poor. Rents would have been shared equally between Russia and Ukraine because both players are necessary for the operating of the system. The resulting net–profit of $ 2.779 bn for Russia compares to $ 4.073 bn which Russia can achieve by forming a coalition with Poland and Belorussia and spending $ 1.296 bn annualized investment cost on Yamal. Russia increases its net–profit, mainly by decreasing Ukraine's share. While total profit declines by app. $ 1.143 bn due to inefficient investment, Russia increases its profits by roughly the same amount. With a $ 0.106 bn each, the shares of Poland and Belorussia are modest, because Russia's outside option, North–Trans–Gas, ensures already a hefty net–profit of $ 3.967 bn.

As to the magnitude, these figures appear to overestimate the distortion if compared to real world investment. While investment in the south was in fact close to zero, the Yamal pipelines has only half of the capacity we predict. This discrepancy between the predictions of the model and reality is not to be resolved by reasonable changes in the numerical values of our parameters. Instead, we see two structural deficiencies of our model which are responsible. First, our model tends to exaggerate the strategic aspect by assuming that investment can take place only once. In reality bargaining over rents is not only influenced by capacities established in the past but also by options to extend the system in the future (Hubert & Ikonnikova (2003)). This will reduce the need to actually spend money on capacities. It is worthwhile to recall that plans, feasibility studies and even some preparatory investment have been made for a capacity of to 56 bcm/a along the Yamal track. Then pipelines with a capacity of 28 have been installed, but investment in compressors stopped short at 18 bcm/a. Given that pipelines are already in place, an increase of capacity by adding compressors is cheap and fast and everyone understands this possibility, hence there is no need to actually waste the money.

Second, our assumption, that players can be clearly separated into those who can commit and those who cannot is overly simplistic. The assumption that Poland and Belorussia can commit, appears not unreasonable for the early nineties, but it is cast into doubts by recent developments. Attaching a small probability of recontracting with either Poland or Belorussia would certainly reduce the appeal of the Yamal project. However, a quantitative assessment of this argument is left for further research.

## 6 Conclusions

In this paper we derive the bargaining power of the different players along the supply chain of Eurasian gas endogenously from the architecture of the transmission system and its possible extensions by applying cooperative game theory for multilateral negotiations. As the number of players is small and the cost parameters of gas transport are well–known, we assume that the members of the Eurasian supply chain bargain efficiently and make the best use of the existing transmission network. This allows us to use the Shapley value to calculate the sharing of profits along the vertical supply chain.

However, in the case of pipelines much of the investment in transport infrastructure is sunk, and therefore prone to ex–post exploitation of quasi–rents. Since there is no international court system to enforce contracts between independent nations, long–term commitments can only be achieved between players who are sufficiently concerned about their reputation. If opportunistic renegotiation cannot be prevented, the well–known hold-up problem may lead to inefficient investment, even if the bargaining process itself is efficient. While we assume that contracts are complete regarding prices and quantities, as is required for the efficient use of the existing network, we allow them to be incomplete with respect to the lifetime of investment projects. This means that at least some players may recontract in order to appropriate quasi rents from sunk investment. Since other players will anticipate recontracting, they may refuse to invest, or overinvest in alternative routes in order to create countervailing power.

Our qualitative and quantitative analysis show that in spite of large capacity cost, overinvestment and excess capacity are not a mere theoretical possibility in the Eurasian transport system for natural gas. Given the particular geography of this network, and the inability to make credible long term commitments or large up–front payments on part of Ukraine, there is in fact much to gain from creating countervailing power. Hence, overinvestment into new pipelines and underinvestment into existing ones are a result of rational strategic calculations.

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