# Strategic Investment and Bargaining Power in Supply Chains:

# A Shapley Value Analysis of the Eurasian Gas Market

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**Abstract**

Russian natural gas is delivered to Western Europe by pipelines, running through Ukraine, Poland and other transit countries. We derive the bargaining power of the different players along this supply chain endogenously from the architecture of the transmission system and its possible extensions by applying the Shapley–Value as a solution concept for multilateral negotiations. Our calculations show that a new link, which has been deliberately design to weaken Ukraine's strong position has in fact little strategic value, while a direct, though very costly, access through the Baltic Sea greatly strengthens Russia. Accounting for the possibility that quasi rents from new investment are prone to opportunistic recontracting, we can rationalize the recent extensions to the system, as a response to Ukraine's lack of credibility in making long term commitments. We also derive predictions about the likely development of the industry in the near future.



Keywords: vertical supply chain, Shapley value, recontracting

JEL class.: L95, L14, C71

# 1 Introduction

Russia is the major supplier of natural gas to Western Europe providing a quarter of the consumption in the region and more than 40% of its imports. Given its large reservoirs and the increasing demand in Western Europe, Russian exports to the region are likely to increase. Gazprom, Russia's dominant exporter, plans to increase the supply from its current level of almost 100 bcm/a by another 50 bcm/a over the next decade. This would allow Russia to remain the largest single supplier of natural gas to Western Europe, with a share of slightly less than 40% of the 350 bcm/a of imports forecasted for 2010.[1] Such a growth of supply, however, requires heavy investment in transport facilities linking consumers in Western Europe to the main pipelines in Western Russia and further on to fields in permafrost regions of Siberia.[2]

Historically, the Eurasian transmission system was developed under long–term agreements, typically ranging from 15 to 25 years. The importing countries often contributed in–kind to investment cost by providing pipes and compressors. 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 and importers could adjust quantities within specified limits according to their temporary needs. 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. And it is difficult to imaging anyone investing in transmission facilities without substantial contract

[1]For more information see Europäische Kommission (2001) and Observatoire Mediterraneen de L'Energie (2002).

[2]Throughout this paper we will refer to 'Western Europe' as the market connected through a dense network of pipelines in central Western Europe, basically the EU-countries excluding Greece. 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.

coverage for the capacity (Stern (2001)).

In Soviet times, transit countries enjoyed only limited freedom to pursue their own agenda and the Soviet Union, keen to establish a reputation for reliability, strictly complied with all its obligations. When the Soviet empire disintegrated, Russia emerged as a central player owning most of the gas fields and essential transport pipelines. At present, even gas–rich Turkmenistan depends on transport through Russian pipelines to reach customers. In this sense, Russia controls critical bottleneck facilities. For the final delivery to the lucrative markets in Western Europe, however, it now depends on transit through independent countries, such as Ukraine, Poland, Belorussia and others. Relations with the transit countries are difficult, as all sides bargain hard for their shares and some players are not willing or able to honor long–term commitments.

This paper analyzes how the balance of power along this vertical supply chain depends on the architecture of the transmission network and how it is and or could be altered through strategic investment in pipeline capacity. As the number of players is small and the basic technologies of gas transport are well–known, we assume the members of the Eurasian supply chain to bargain efficiently and 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 and the various options to modify it. In particular, we can calculate the strategic value not only for existing pipelines but also for various options to extend the system through investment.

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 maintained 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 the project. 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 weaken the bargaining power of their opponents in ex–post negotiations.

As new links add to transmission capacity, their economic viability depends also on future demand in Western Europe and the cost of the development of new fields serving this demand in Russia. With respect to these parameters we look at different variants to assess the robustness of our results and to disentangle the strategic aspects of investment from simple commercial reasons to increase the capacity. Recent investments in the Eurasian transmission network as well as plans for further pipeline connections reflect to a large extend Russia's desire to strengthen its strategic position vis-á-vis transit countries — in particular Ukraine. Our quantitative assessment reveals that some projects which look commercially feeble are, nevertheless, very important for strategic reasons. Others, which have been deliberately drawn up to alter the balance of power, turn out to be strategically irrelevant. The renovation and upgrading of the system in Ukraine would provide a cheap way to increase capacity, but the country is considered as a player who cannot credibly commit to adhere to long–term agreements. Our calculations show that expanding facilities in the Ukraine would strengthen this country too much in ex–post negotiations to make the project interesting for the other players.

In the European market, Russian gas faces competition from Norway accounting for 25% of imports and from 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,

[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

Algeria and Norway interact and how they jointly react to the thread 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.

Hitherto, only Grais & Zheng (1996) and Chollet & Meinhart & von Hirschhausen & Opitz (2001b) attempt a rigorous and 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 by applying the Shapley value (cooperative game theory). Instead, they assume that Russia has all the bargaining power by giving it a first mover advantage. This would allow Russia to extract the whole rent if contracts covered prices and quantities or if it could set non–linear prices. However, in this literature it is assumed that Russia can commit only to simple linear prices. With this restriction, competition among transit countries determines the quantities supplied to the markets in Western Europe and profits are inefficiently low due to double marginalization.

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 studies of industrial organization. Hence, the paper also pioneers the practical application of a concept, which in theoretical analysis is widely seen as the only convincing solution to the problem of multilateral bargaining.

In the next section, we briefly describe the development of the supply chain for gas, recent conflicts between the players and options for modifications of the system. Section 3 describes our analytical approach. In section 4 we motivate our assumptions

(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).

on parameters. In section 5 we quantify the strategic value of investment and analyze the relation between bargaining power, recontracting and investment. 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 it could use an appendix to the Brotherhood line, transporting gas from Eastern Ukraine to Czechoslovakia, to connect to Austria and Germany (see figure 1). As exports increased during the seventies and eighties, additional transmission capacities were established alongside previous routes, which were linked to new fields in the southern Ural (Orenburg) by the Sojus line. Somewhat 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. Here, the only transit country, Czechoslovakia, had been occupied by Soviet troops in '68 and was governed by a loyal regime ever since.

When the Soviet Union finally collapsed, however, Russia found itself in the uncomfortable position that 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 benefited from old contracts with the Soviet Union, which entitled them to large deliveries of gas at low cost which helped to smooth the transition to market pricing. In the following, both countries privatized 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.

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

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

Figure 1: Eurasian Transmission Network in Soviet Times

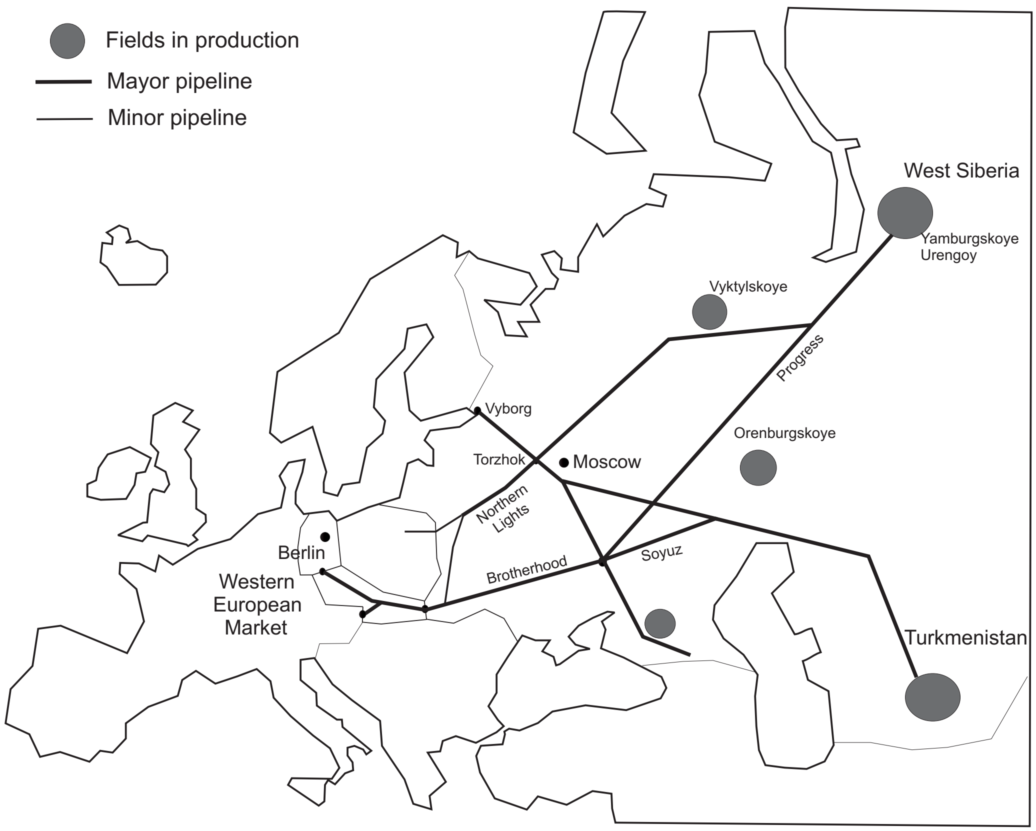
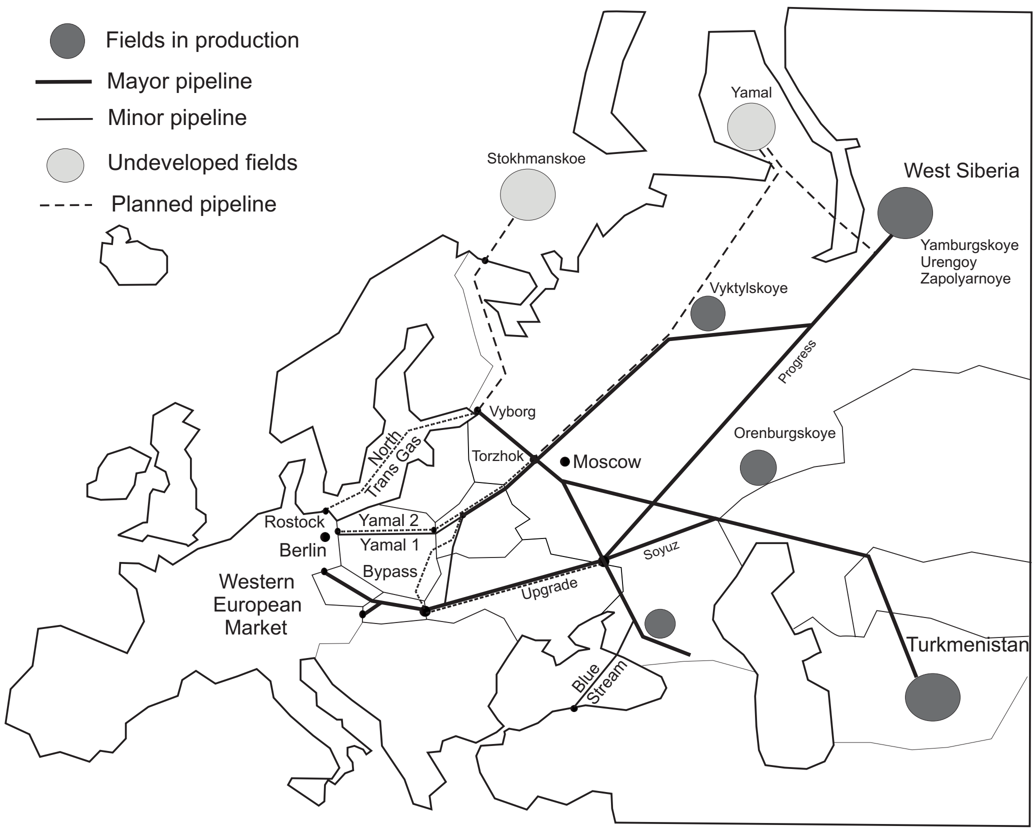


Figure 2: Current Eurasian Transmission Network



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 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 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. On this background, even partial solutions of the protracted conflicts repeatedly failed. In the latest attempt, the 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]

Meanwhile, due to aging compressors, lack of maintenance and underinvestment, the capacity of the transmission network, currently estimated at 90 bcm/a, is in decline. Upgrading the transit system in the Ukraine would provide the cheapest option to increase transmission capacity. But during the nineties, even attempts to ensure proper maintenance failed. In autumn 2002, Russian Gazprom and Ukrainian Naftogas 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 the Ukraine have the potential for another 35 bcm/a, which would require complementary investment in Slovakia and in 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

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

control of its network in exchange and there is little concrete progress on this sensitive issue so far. Given the dismal record of previous agreements, doubts remain whether this time a solid commercial solution was found.

Eager to diversify its export channels, Russia turned to Belorussia and Poland. Belorussia' ties with Russia remained very close and its ability to act independently appears to have been quite 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. 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' (for an illustration see figure 2).[7] Progress on *Yamal 1* has been slow. Its current capacity of 18 bcm/a is scheduled to reach 28 bcm/a over the next years by adding compressors. This would complete the first stage at an estimated cost of $ 3.4 bn. Provisions have been made for a further doubling of the capacity to 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 disputes both with Poland and Belorussia.

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.[8] Since this link can also be seen as part of the larger Yamal project it is sometimes referred to as Yamal 2. However, if realized without addi-

[7] 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.

[8] Gazprom would be in charge of the section in Belorussia. For Poland and Slovakia a consortium was set up including among others Gazprom (18%), PGNiG (10%), SNAM (29%), Ruhrgas (22%), GdF (12%), Wintershall (5%).

tional investment towards customers in the West (and fields in the east) it would mainly serve to bypass Ukraine, hence, we will refer to this project as *Bypass*. With an estimated cost of $ 4 bn the *Bypass* has limited commercial value in a narrow sense because it does little to increase transmission capacities westwards. Nevertheless, offering an alternative to the route through Ukraine, its strategic value is potentially large. So far, no timetable for investment has been set, and it appears as if the project has been shelved with the recent agreement between Russia and Ukraine.

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 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 the North Trans Gas project for the strategic value of a direct access to its largest market in the West.[9]

The post Soviet developments in the Eurasian transport network for natural gas reflect to a large extent Russia's reactions to the strength of Ukraine's position in the inherited system. Moves such as the diversification of export routes and plans for a bypass, can be understood as a deliberate attempt to gain leverage over the neighbor, perceived to be obstructive and excessively demanding. While the cost of establishing alternative supply routes are known, at least by order of magnitude, the strategic gains are difficult to discern. It requires a formal model of how network

[9]In the south, a similar project, the *Blue Stream* pipeline through the Black Sea to Turkey, has moved beyond planning stage. The first of two pipelines 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.

architecture and investment options determine the power of the different players and the sharing of profits from gas exports. This framework can then be used to analyze whether building Yamal helped Russia to strengthen its bargaining position. We can assess how important the Bypass is to discipline Ukraine. What is the effect of further, even more costly, options to diversify export routes such as North Trans Gas.

A quantitative analysis of the strategic interaction is also needed to understand why the cheapest option for extending the systems capacity, the upgrade of the Ukrainian network, was not chosen in the early nineties, and whether recent changes in network configuration make it more likely that this will happen in the near future.

In order to obtain a fairly comprehensive picture of the network architecture we take into consideration the old system through *Ukraine*, the possibility to *Upgrade* it, current *Yamal* and its possible enlargement, the *Bypass*, and *North Trans Gas.* As to the players we confine ourself to *Russia*, *Ukraine*, *Poland*, and *Slovakia.* Given the close connection between Russia and Belorussia during the 90th we do not consider the latter as an autonomous player. In view of the developments since 2001 this is not fully satisfactory and will be modified in future research.

# 3 Bargaining Power, Network Architecture, and Strategic Investment

As mentioned in the introduction, we want to derive the bargaining power of the parties from the architecture of the transmission grid. Intuitively, the power of a player should increase as he becomes more 'important' for other players, which will depend on his control over gas fields and transport routes. In this section we explain how we can measure exactly the 'importance' of a particular player by looking at the contributions he can make to the various possible coalitions.

Let $n$ denote the total number of players which may form arbitrary coalitions $S$ with $s \leq n$ players. We will represent the strategic interaction along this supply chain by the so called 'value function' $\pi(S)$, that is the payoff which a coalition $S$ can assure for itself. Obviously, any change in demand for gas, network architecture, transportation cost etc. will yield a new function $\pi$. A potential problem with the value function approach is that a coalition's payoff may depend on what the excluded players do. Fortunately, this problem does not arise in our case because Russia is an essential player. Whether transit countries act alone or form coalitions, they will not be 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 most common solution for games represented in value function form is the Shapley value.[10] It calculates the payoff $\phi_i$ of player $i$ as his expected contribution to all possible coalitions, assuming that all possibilities are equally likely:

$$\phi_i(\pi) = \sum_{S:i \notin S} \frac{s!(n-s-1)!}{n!} \cdot [\pi(S_{+i}) - \pi(S)],$$

where the first term in the summand gives the probability of a particular coalition $S$ and the second the marginal contribution of the player $i$.[11] The Shapley value derives the payoffs of the players from the fundamentals of the problem. Any two players contributing the same to all possible coalitions receive equal payoff (symmetry). In this sense the 'bargaining power' is assumed to be equal. Only the differences in the strategic positions of the players yield different shares of profit. However, in this paper we want to compare different networks layouts, i.e. different value functions, and it is convenient to refer to the relative share of a player, $\sigma_i(\pi) = \phi_i(\pi)/\sum_{-i}\phi_j(\pi)$, as his 'bargaining power'. Hence, we will speak of player $i$ gaining

[10] As Shapley (1953) has shown, it is the only rule for sharing the profits from multilateral co-operation 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.

[11] The Shapley value can be interpreted as follows. Suppose the grand coalition of all players is being formed in a sequence by including one player at a time. In general, the marginal contribution of a particular player depends on his position in the queue, which is determined randomly. When joining a sub–coalition $S$, a player $i$ receives the amount by which his inclusion increases the profits of the group, $\pi(S_{+i}) - \pi(S)$, (the second term in the summand). There are $n!$ possible orderings of the players in total. The number of possible sequences to obtain a coalition $S$ before player $i$ joins is $s!$, and there are $(n-s-1)!$ possible ways to continue thereafter. Hence, the overall probability of $i$ entering the coalition $S$ is $(s!(n-s-1)!)/n!$ (the first term in the summand). By summing up over all possible coalitions not including player $i$ we obtain the expected contribution.

in bargaining power from a change in network architecture if the corresponding change in the value function from $\pi_0$ to $\pi_1$ implies $\sigma_i(\pi_1) > \sigma_i(\pi_0)$.

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–profit sharing. Meanwhile, the theoretical literature has proposed a number of solutions to this problem. Gul (1989) shows that the Shapley value can be obtained as the ex–ante expected profit from sequential exchange assets (rights). At each round the players match randomly in pairs and trade. Those who sell their assets leave the game. The value of the assets which a player accumulated after a certain period of time equals the profits of a coalition which includes all 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.

Stole & Zwiebel (1996a) and Stole & Zwiebel (1996b) 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 turns out to be renegotiation–proof, if the gains in pairwise negotiations are split equally. The particular order of players does not matter in this context because renegotiations occur with all remaining players if one player leaves a coalition. We do think, that their model fits real world bargaining in the gas market particularly well. Russia, is a central player in their sense 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 any investment is undertaken.

Finally, Inderst & Wey (2001) motivate the use of the Shapley value by assuming 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.

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 capacity generates large quasi–rents raising two related questions. First, are the players able to commit themselves to a particular sharing of rents ex-ante or are they prone to haggling over their distribution at the post-investment stage? In the latter case, previous investment in transport capacity strengthens the bargaining power of those in control of the facilities. This raises the second question, namely whether investments are distorted in order to create countervailing power.

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. Investment in transport capacity is verifiable, and so are most contract violations during the operating stage. This is confirmed by the fact that in the past many of the investments in transport capacity have been arranged under comprehensive long–term contracts. If all parties could make these long–term commitments, we can take all technical possibilities to modify the transport grid into account and minimize transport cost, fully taking into account initial investment cost. The corresponding value function will be denoted $\pi^+$.

However, 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 in breach of contract. Since external enforcement of the agreements is insufficient, commitment can be only credible if players are sufficiently concerned about their reputation. Russia, for example, has worked hard to establish a reputation for reliability in this market for more than two decades, and followed this policy even in phases of internal turmoil. It would scarify this reputation if it defaults on its obligations to achieve short run gains. Others are heading towards EU integration, making it essential to be accepted as reliable 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 which pays off only in the distant future. Given the fragility of its political system, it appears highly unlikely the other players would trust any long–term commitment at face value. Thus, we treat players differently and assume that it is generally expected that Ukraine will recontract if it is in its interest to do so.

When contemplating the various possibilities to invest in the pipeline system and bargaining over the sharing of profits, rational players will anticipate recontracting after the investment has been completed, if the added capacity is under control of an unreliable player. For those links investment cost would be sunk and irrelevant for the bargaining outcome. Let $\pi^r$ denote the corresponding value function. As $\pi^r$ ignores sunk cost it will be true that $\pi^r(S) \geq \pi^+(S) \ \ \forall S$. The players would know in advance that the sharing of quasi–rents would be according to $\phi(\pi^r)$. Still, there is no need to distort investment because the sunk cost of the initial investment $c$ can be shared to ensure that, $\phi_i(\pi^r) - c_i = \phi_i(\pi^+) \ \ \forall i$. Those players who expect to earn from recontracting would simply have to contribute a larger share of the initial investment cost. If the time–profile of payments does not matter, little is lost by looking at $\phi(\pi^+)$, which is still the sharing of expected profits ex–ante.

As the calculations below show such a front–end–loaded implementation of the Shapley sharing would require Ukraine to pay large amounts up–front, which the cash–strapped country may not be able to afford. Its access to international capital markets is restricted for quite the same reasons which raise doubts about its commitment in the gas market. If financial constraints in combination with limited commitment prevent the implementation of the Shapley value investment may be distorted. Let $\pi^-$ denote the value function if there is no investment to upgrade the Ukrainian system. The efficiency loss from distorted investment would be $\sum_i (\phi_i(\pi^+) - \phi_i(\pi^-))$. This loss may lead to a deviation from Shapley sharing.

The maximal amount $p_i$ player $i$ is prepared to pay up–front for the upgrade of the Ukrainian system when he expects recontracting is $p_i = \phi_i(\pi^r) - \phi_i(\pi^-)$. There are two possible cases. Depending on the parameters it may turn out that $\sum_{i \neq U} p_i$ is large enough to cover the sunk cost. In this case, the other players are ready to pay for the investment up–front. Investment would be efficient, but the ex-ante sharing would be different from $\phi(\pi^+)$. If, however, $\sum_{i \neq U} p_i < c$, then there would not be enough interest to finance the investment, total profits were inefficiently low, and the bargaining power were given by $\phi(\pi^-)$.

# 4 The Value Function

The profit which a particular coalition can achieve depends on demand for Russian natural gas, on production cost and on the cost of transport routes which are available for this coalition. The latter depends on the geographical location of its members, on past investment in transport facilities, and on options to extend the system.

### Demand & Production Cost

To simplify our analysis, we assume that demand and production cost are independent of transport routes to the west. On the demand side 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 gas from Siberia by gas from Turkmenistan and vice versa.

The demand for Russian natural gas is determined by 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. The annual figures for average gas prices given in the statistics 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. Therefore, we have to resort to 'plausible' assumptions and then consider a range of possible parameters to assess the robustness of our analysis.

For simplicity, we take a linear specification of the demand function and assume that marginal production cost are constant.[12] Pipelines have a life expectancy of about

[12] According to the terminology in this paper, production cost include the cost of transporting

25 years. Hence, for any new investment we have to make assumptions about the development of future demand and the development of new gas fields to serve this demand.

A lower bound is obtained from Chollet & Meinhart & von Hirschhausen & Opitz (2001) who consider a linear demand schedule with intercept 58 and slope 0.18, yielding a price of 41 $/tcm at a quantity of 100 bmc/a and production cost of 9.1 $/tcm. From figures on current and future marginal cost of non–Russian suppliers provided in Observatoire Mediterraneen de L'Energie (2002) we estimate much higher residual demands for Russian gas with intercepts in the range of 120 to 140 and slopes 0.35 to 0.55, yielding prices in the range of 70 to 80 $/tcm.[13] The cost of Russian gas tends to increase as production from old low cost fields declines and new, more expensive fields have to be developed. The cost of current production from recently developed fields such as Zapolyarnoye may be in the range of 10 to 11 $/tcm, which is also a reasonable figure for gas from Turkmenistan. However, cost may easily increase up to 15 $/tcm if fields like Stockman or Yamal have to be developed.[14]

### Transportation Cost

The total cost of transporting gas can be decomposed into capacity cost $c$ and operating cost, the latter consisting of management and maintenance cost $m$ and energy cost. For pipeline technology, the cost of providing transport capacity is roughly proportional to distance and the same is true for maintenance. However, energy costs, largely consisting of the value of the gas which is consumed by compressors, are more difficult to calculate because the price of gas increases along the way. As

gas to the major link connecting Torzhok with eastern Ukraine.

[13]Rather than estimating the demand for gas from consumption data we take the total consumption of gas as exogenously given and derive the residual demand for Russian gas from the cost of competing suppliers. The approach is based on the assumption, that a reduction (increase) of supply from Russia would lead to an increase (decrease) of supply from alternative sources. In a perfectly competitive market the associated changes in price would be determined by the cost of the marginal supplier who has to replace (is driven out by) Russian gas. As the gas market is not perfectly competitive, gas trades at a 'mark up' on marginal cost in the range of 20%.

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

the fraction of gas used over a given distance is roughly constant, transport cost $t$ can be calculated according to

$$t(y) = \left(\frac{c+m}{g} + p_0\right)(e^{g \cdot y} - 1) \quad (1)$$

where $y$ denotes the distance, $p_0$ the price of gas at the source, and $g$ the fraction of gas per distance which is needed for pressurizing.[15]

As we express all figures on an annual basis, we obtain the 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.

We assume that operating cost are proportional to quantity. However, there are several types of economics of scale in providing transport capacity. Some are related to the pipeline itself, others are gains obtained from laying pipelines along the same track. The capacity of a pipeline increases in pipe diameter and the pressure it can withstand. Holding pressure constant, the cost per unit of pipeline capacity decrease in pipe diameter. However, this type of 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.[16] Hence, for large additions to capacity we generally assume that investment costs are proportional. In some cases, however, we look at smaller increments and will take economics of scale into account.[17] A

[15]Since there is sometimes confusion about the calculation of energy cost we explain how the formula can be obtained. Suppose the price of gas at $y$ is $p(y)$ and we want to transport one unit gas by a small distance $\Delta y$. Then, the transportation cost per unit gas can be obtained by asking how much its price has to be increase along $\Delta y$ in order to cover the cost: $p(y+\Delta y) - p(y) = [(c+m) + g \cdot p(y)] \cdot \Delta y$. Dividing by $\Delta y$ and taking the limit, we obtain: $p'(y) = (c+m) + g \cdot p(y)$. The solution to this differential equation

$$p(y) = p_0 e^{g \cdot y} + (e^{g \cdot y} - 1)\frac{c+m}{g}$$

gives the price of gas at any location $y$. By deducting $p_0$ we obtain the increase of price between 0 and $y$, that is the cost of transport $t$, given in the text. Note that $\lim_{g \to 0} t(y) = \lim_{p_0 \to 0} t(y) = (c+m)y$ as we would expect.

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

[17]For long–distance transmission lines there appears to be a standard technology, representing the ‘state of the art’ for new investments. Typical for onshore lines are pipes with 56 inch (1420mm) diameter and 84 – 100 bar pressure, while offshore lines tend to be smaller in diameter (42-48 inch) but with higher pressure (120-150 bar).

typical onshore pipeline yields an annual capacity of about 30 bcm and will cost about 120 mln$/100km, of which 35% are cost of assembling, 20% planning and services and about 45% the material. Larger capacities are achieved by adding pipes not by increasing the diameter.

There are several reasons to install additional pipes parallel to existing ones (track economics of scale). Depending on the difficulty of the terrain, the cost of preparing the ground, building supply roads, etc may add another 20–45 mln$/100km to the cost of the first pipeline, much of which can be avoided by using established tracks. In order to obtain the optimal capacity, the initial cost of complementary compressor power will be in the range of 50 mln$/100km a fraction of which provides backup capacity needed for reliability reasons. Parallel pipelines allow the sharing of compressor power and to economize on backup facilities. Finally, an isolated new pipeline has to bridge the whole distance before supplying the first gas, whereas along existing tracks capacity can be increased gradually and therefore more timely adjusted to the growth of demand.

For convenience table 1 summarizes the main features of the various pipeline links already described in section 2. With respect to the Yamal project we look at several variants in order to account for the sunk cost nature of investment and economics of scale. Yamal A corresponds to the ex ante perspective in the early nineties before work the project started. At present Yamal Aa is in place and can be extended stepwise by Yamal Ab and Yamal B.

From this information we can calculate the total transport cost along the various routes (see table 2). First we annualize investment cost which are then inflated for new projects by 15%. Cost of maintenance are $m = 0.1\$/tcm/100km$ for onshore pipelines, and double this amount for offshore pipes. Energy cost are 0.25% of gas /100km, and double for the old system in Ukraine and for offshore pipelines.

The last column in table 2 gives the total variable cost of transporting gas along a particular link. As investment cost are already sunk, the existing pipelines in Ukraine and Yamal Aa offer the cheapest way to transport gas. If capacities are to be increased, completing the first part of Yamal (Yamal Ab) and renovating the Ukrainian system will be the most efficient ways of doing this. Here the main task is to install additional compressor power at pipelines which happen to operate below full capacity In these situations the capacity effects of marginal investment are very

Table 1: Description of Transport Links for Russian Gas

| | capacity [bcm/a] | invest-ment[c] [bn$] | length[a] [km] | players[b] |
|---|---|---|---|---|
| Ukraine existing | 70[d] | sunk | 2000 | Russia, Ukraine |
| | A system of parallel pipelines, gas storages, compressors, mostly depreciated and in poor state of repair. | | | |
| Ukraine upgrade I | 15 | 0.75 | 2000 | Russia, Ukraine |
| | Mostly repairs and replacement of compressor power. | | | |
| Ukraine upgrade II | 35 | 3.1 | 2700 | Russia, Ukraine |
| | Additional pipes on the Slovakian territory parallel to old system | | | |
| Yamal A | 28 | 3.4 | 1600 | Russia, Poland |
| | Frankfurt/O — Torzhok. As the pipeline is already finished, this is an ex–ante perspective of the project. | | | |
| Yamal Aa | 18 | sunk | 1600 | Russia, Poland |
| | Present state of Yamal project. | | | |
| Yamal Ab | 10 | 0.4 | 1600 | Russia, Poland |
| | Completion of Yamal A by adding compressor stations. | | | |
| Yamal B | 28 | 2.4 | 1600 | Russia, Poland |
| | Parallel to Yamal A. | | | |
| North Trans Gas | 30 | 4.2 | 1600 | Russia |
| | Greifswald (Germany) — Vyborg (Russia) 1200 km offshore, 400 km onshore to Torzhok. Originally planned for 18 bcm/a. | | | |
| Bypass | 60 | 3.6 | 1400 | Rus., Pol., Slovakia, *not Ukraine* |
| | Velke Kapuzany — Torzhok. Assumed to use capacities in Slovakia and Tzech Republik which are only available if the network in Ukraine is not used. | | | |

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

[b]Players needed to use or establish the connection.

[c]Estimated investment cost obtained from various sources.

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

Table 2: Cost of Transportation

| | capacity [a] | maintenance | energy | total cost[b] |
|---|---|---|---|---|
| | [$/tcm/100km] | [$/tcm/100km] | [% gas/100km] | [$/tcm] |
| Ukraine old | sunk | 0.1 | 0.50 | 14.26 |
| Ukraine Upgrade I | 0.39 | 0.1 | 0.25 | 21.54 |
| Ukraine Upgrade II | 0.69 | 0.1 | 0.25 | 33.88 |
| Yamal A* | 1.35 | 0.1 | 0.25 | 35.12 |
| Yamal Aa | sunk | 0.1 | 0.25 | 13.08 |
| Yamal Ab | 0.38 | 0.1 | 0.25 | 19.39 |
| Yamal B* | 0.95 | 0.1 | 0.25 | 28.63 |
| North Trans Gas* | 1.80 | 0.2 | 0.50 | 49.82 |
| Bypass* | 0.76 | 0.1 | 0.25 | 27.38 |

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

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

[b]Total supply cost, according to formula 1 adding 11$/tcm for the cost of gas at the Russian export node.

large, and, as the construction period is short, there is little interest payed before revenues are increased.

Only if these options are exhausted should capacities on Yamal be added (Yamal B). Coalitions not including Ukraine would prefer the Bypass to Yamal, to make use of the otherwise unused capacities in Slovakia and Tzech Republic. The North Trans Gas project is the most expensive variant.

# 5 Strategic Value and Investment in Pipelines

In table 3 we present the Shapley values for various assumptions over the availability of pipeline connections. The first figure in each pair of columns gives the absolute payoff in million dollars per year. The second gives the player's share of total profits, which can be interpreted as his relative bargaining power. Demand for gas and production cost have been chosen to be compatible with current transport capacities. Hence, there would be no commercial interest to increase capacity and the available options for investment would not be used.

The first two columns give the result for the hypothetical case that the currently existing network could not be changed, i.e., no new pipelines or capacity increases would be possible. As capacities through Ukraine and Poland are both restricted, competition between the two players remains very limited. Russia would obtain 55%, which is slightly more than the 50% that it would get if all pipelines would run through one transit country only. However, the picture completely changes if we take into account the various possibilities to change the transmission grid. As the figures in the second pair of columns show, Russia now obtains the lion's share of 80% of the profits, while Ukraine and Poland are down to 13% and 7% respectively.[18] Although none of the additional links or capacities would be used, the mere possibilities of delivering gas through the Baltic Sea, increasing capacities

[18] In this case we obtain the following value function: $\pi(R) = \pi(R,S) = 2551.0$ mln\$, $\pi(R,U) = \pi(R,U,S) = 5177.5$ mln\$, $\pi(R,P) = 4449.4$ mln\$, $\pi(R,U,P) = 5327.5$ mln\$ , $\pi(R,P,S) = 4515.8$ mln\$ , $\pi(R,U,P,S) = 5327.5$ mln\$, and $\pi(\cdot) = 0$ for all others. We are cautious with the absolute numbers, as they depend much on our assumptions on demand and production cost and the gains of increased bargaining power may accrue in non–monetary form. Nevertheless, it is worthwhile noting that our figure of about 700 mln$ profit for Ukraine corresponds well to estimates in Opitz & von Hirschhausen (2001)

Table 3: Availability of Pipelines and Bargaining Power

| | Shapley values in mln$/a and percent | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | status quo[a] | | all options | | excluding one option at a time | | | | | | | |
| | | | | | Bypass | | NTG | | Yamal | | Upgrade | |
| Russia | 2928 | 55% | 4236 | 80% | 4231 | 79% | 3386 | 64% | 4126 | 77% | 4209 | 79% |
| Ukraine | 1978 | 37% | 714 | 13% | 730 | 14% | 1139 | 21% | 839 | 16% | 687 | 13% |
| Poland | 421 | 8% | 372 | 7% | 366 | 7% | 797 | 15% | 262 | 5% | 426 | 8% |
| Slovakia | 0 | 0% | 6 | 0% | 0 | 0% | 6 | 0% | 101 | 2% | 6 | 0% |

[a]Demand has intercept 130 and slope 0.63, production cost are 11 $/tcm, yielding a total profit of 5.328 bn$/year at current capacities, which are optimal.

on Yamal and the Ukrainian system strengthens Russia's bargaining power.

To find the strategic value of each options, we delete one option at a time. Comparison of the second and the third pair of columns shows that the strategic value of the Bypass is small. Its impact on Russia is negligible and there is only a small amount of redistribution between Poland and Ukraine. Even Slovakia gains very little. This stands in marked contrast to the strategic impact of the North Trans Gas project. The presence of this option increases Russia's share of profits by 950 mln $/year, raising its bargaining power from 64% to 80%. In our view, this explains Russia's interest in a project, which from a naive point of view, i.e. without accounting for strategic interaction, makes pretty little economic sense due to its high cost. For small additions to the capacity, Yamal is currently the cheapest, hence, commercially the most interesting option. Its strategic value, however, is fairly limited. The strategic role of the option to upgrade the Ukrainian system is even weaker, although this provides an opportunity to add substantial capacity at low cost.

In order to interpret these results it is useful to consider briefly how geography and cost interact to determine the Shapley Values. Suppose that all pipelines would have equal unit–cost, so that total profits were the same for all possible connections. If the only possible transmission route was through Ukraine, then Russia and Ukraine would share the profits equally. Both are indispensable and there is no reason why any one should have a strategic advantage. If we introduce an equally efficient route through Poland, Russia would obtain two thirds of the profits and Ukraine and Poland would share the rest equally.[19] However, if Russia can establish a direct offshore link on its own, it obtains the whole profit, as there is no need to share with anyone. Now, assume that pipelines differ in their cost, either because of different conditions (NTG vs. Yamal) or because investment costs are already sunk (Ukrainian system, Yamal Aa). Loosely speaking, Russia would start with the profits which it would obtain if the direct link were the only connection to Western Europe. While North Trans Gas looks inefficient in comparison to the other options, standing alone it would still be highly profitable. In addition, Russia will obtain 2/3 of the increase in profits obtained from switching from the offshore to the next best onshore option and 1/2 of the difference of profits between the two onshore options. The North Trans Gas strengthens Russia with respect to all possible coalitions and has therefore a strong impact on its bargaining power. In contrast, all coalitions which can realize the Bypass can also realize Yamal, which is just marginally less profitable. Hence, its strategic impact is negligible.

These results are confirmed when we assess the robustness of our calculations with respect to parameter changes (see table 4). The first pair of columns corresponds to the second pair in table 3. Although we look at a somewhat stronger demand now, for which the optimal capacity is 113 bcm/a and profits raise to 7193 mln$/a, the bargaining power remains almost the same. The three pairs of columns to the right give the change in percentage point of bargaining power as a result of a change in the parameter values. As the last two indicate, a ten per cent decrease in investment cost of the North Trans Gas Project leads to a 1.4 percentage point increase of Russia's bargaining power, while a ten per cent increase of cost would decrease Russia's bargaining power by 1.4 points. We do not report the corresponding results for the other links here because the figures are always less than half a percentage point. Hence, we conclude that with respect to investment cost, our results are fairly robust, with the possible exception of the NTG project. A similar claim can be made for the production cost. Within the range of 9 to 15 $/tcm the bargaining power would change only little.

[19] With profits normalized to one, the value function would be: $\pi(R) = \pi(U) = \pi(P) = \pi(U,P) = 0$, $\pi(R,P) = \pi(R,U) = \pi(R,P,U) = 1$ and the Shapley values would be $\phi_R = 2/3$, $\phi_U = \phi_P = 1/6$.

Table 4: Sensitivity of Bargaining Power to Changes in the Parameters

| | Base Variant[a] | | Cost of gas[b] | | Demand | | NTG | |
|---|---|---|---|---|---|---|---|---|
| | | | 9 | 15 | Low[c] | High[d] | -10% | +10% |
| Russia | 5723 | 79.6% | 0.4 | -1.1 | -19.3 | 3.1 | 1.4 | -1.4 |
| Ukraine | 872 | 12.1% | -0.2 | 0.6 | 14.5 | -3.8 | -0.7 | 0.7 |
| Poland | 592 | 8.2% | -0.1 | 0.5 | 4.7 | -1.8 | -0.7 | 0.8 |
| Slovakia | 6 | 0.1% | 0 | 0 | 0 | -0.1 | 0.1 | 0 |

[a]Demand has intercept 130 and slope 0.45, production cost per unit are 11$ yielding a price of 76 $/tcm and a total profit of 7193 mln$/year at a capacity of 113 bcm/a.

[b]Measured in $/tcm

[c]Demand is taken from Chollet & Meinhart & von Hirschhausen & Opitz (2001) with intercept 58 and slope 0.18, yielding a price of 39$ at a capacity of 104 bcm/a.

[d]Demand has intercept 150 and slope 0.30, yielding a price of 87$ at a capacity of 192 bcm/a.

With respect to demand we consider rather drastic changes. As a rule, an increase in demand strategically benefits Russia because it requires new investment, for which Ukraine and Poland compete on fairly equal terms. At the same time, the increase in capacity tends to decrease the Ukrainian share of profits because old low cost connections, on which its power is built, carry less weight in the total capacity. An increase of demand that drives prices and capacities up to 87$/tcm and 192 bcm/a would increase Russia's bargaining power by 3.1 points and weaken the Ukraine by 3.8 points. For such an increase these changes appear to be modest. The variant taken from Chollet & Meinhart & von Hirschhausen & Opitz (2001) features a very small intercept and a large price elasticity. Hence, optimal quantities are fairly large at 104 bcm/a but the price is as low as 39 $/tcm. This scenario would substantially change our results, decreasing the Russian share by almost a quarter and strengthening Ukraine and Poland by 14 and 4 percentage points, respectively.

As mentioned previously, upgrading the depreciated transmission system in the Ukraine offers one of the cheapest ways to increase the capacity. However, the Ukraine is also the player least credible in its long–term commitments. Now we

Table 5: Recontracting and Upgrading of the Ukraine System

| | Commitment[a] $\pi^+$ | | Recontracting $\pi^r$ | | no Upgrade $\pi^-$ | |
|---|---|---|---|---|---|---|
| Russia | 5723 | 79.6% | 5748 | 78.6% | 5583 | 78.8% |
| Ukraine | 872 | 12.1% | 897 | 12.3% | 732 | 10.3% |
| Poland | 592 | 8.2% | 660 | 9.% | 766 | 10.8% |
| Slovakia | 6 | 0.1% | 6 | 0.1% | 6 | 0.1% |
| All together[b] | 7193 | | 7312 | | 7087 | |

[a]Demand has intercept 130 and slope 0.45

[b]The difference between first and second column is due to sunk costs of Ukraine upgrade. The difference between first and third column is due to higher cost of Yamal.

will analyze how this lack of commitment power, combined with restricted access to financial markets, leads to inefficient investment. We do this in two steps. First, we ask whether in the current situation investment in the Ukrainian system is likely to go ahead even if all players expect recontracting. Second, we move back to the early nineties, before the Yamal project had been started, and ask why this much more expensive variant had been chosen.

The figures in table 5 refer to the same situation as in the previous table. Looking forward, we choose a demand function reflecting the expected growth in demand. Optimal capacity would be reached at 113 bcm/a and the most efficient way to achieve this is to finish the first part Yamal, adding 10 bcm/a and then to reinvest in the Ukraine to obtain another 15 bcm/a. The annualized sunk cost of the investment in the Ukraine would amount to 142 mln$. The second pair of columns in table 5 displays the sharing of profits if these cost are ignored. This is the result the players would expect in the case of recontracting after the investment was made. As the difference between the total profits are just the sunk cost, it would be possible to share the initial investment cost in order to achieve exactly the results of the first column. However, this would require the Ukraine to contribute to the investment cost. If this is not possible, the players have to contemplate the next best option without investment in the Ukraine. The corresponding figures are given in the last pair of columns. Here we calculate Shapley values for the case when investment in the

Ukraine is not undertaken. In principle, the other players could gain from financing investment in the Ukraine even if they expect recontracting, provided the difference between their profits in the no–investment scenario and the recontracting scenario are sufficiently large. However, given that we have already invested in Yamal, this turns out not to be the case. Their maximal contribution in terms of annualized cost is 59 mln$, which is not enough to cover the sunk cost of 142 mln$.[20] Hence, unless the reputation of Ukraine or its access to finance improves, the prospects for renovating its system look poor.

Finally, we want to explore whether this kind of reasoning is able to explain the recent development of the industry. To this end, we 'move' back to the early nineties, when the decision had to be made whether to invest in the Ukrainian system or to built the first part of Yamal. Demand for gas turned out to be weak throughout most of the nineties, therefore we assume that players expected a demand for which current capacities are optimal. The only difference to the situation analyzed in table 3 is that the cost of the first step of Yamal had not been sunk at that time. It turns out that this makes the Ukraine option so much more attractive that the other players should have made the investment even if Ukraine could contribute nothing up–front and was expected to recontract afterwards. The advantage of investment in the Ukraine is particularly large when we account for economics of scale in the Yamal project. Thus, at first glance, we obtain the counterfactual result that Yamal should never have been started.

However, this result depends on both the size of the efficiency loss and the impact of investment on the bargaining power of the players which in turn depends on the options considered to be available. As we have seen the North Trans Gas project has the greatest strategic impact. However, in the early nineties, this project must have appeared quite remote. While the Yamal project lingered around throughout the eighties, the option to go straight through the Baltic sea became concrete only during the nineties.[21] If the NTG option had no influence on bargaining power, Russia's position would have been much weaker and it stood to lose much more

[20]Note, that Russia alone would have an interest to finance the project as it stands to gain 189 mln$. However, Poland would step in and 'bribe' Russia not to invest, because it would loose about 100 mln$.

[21]Earlier plans focused on the Baltic Ring which would have connected all northern countries before linking up to the German Grid.

from recontracting with the Ukraine. Applying the same logic as before, we find that in the early nineties both, the first part of Yamal and the investment in the Ukraine have been possible outcomes, with a slight advantage for the latter if we account for economics of scale.

## 6 Conclusions

In general it is difficult to make use of the Shapley value in applied research. In order to calculate it, the optimization problem of every conceivable sub–coalition of players has to be solved. 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 the concept. For example, in the present context, we have to figure out what would happen if Russia were denied transit through Poland and Ukraine, i.e., which supply routes Russia would establish at what cost and how much gas it would deliver to Western Europe. Probably there are only a few markets for which there is enough information available, so that it is possible to calculate the profits for situations as 'unreal' as this one with reasonable accuracy.

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 of the Shapley value in applied research.

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 are able to quantify the strategic importance of single options. The 'Bypass' is a pipeline explicitly designed to shortcut Ukraine through Poland and Slovakia. What at first glance may look as a powerful threat to Ukraine's strong position in the current network turns out to have negligible strategic relevance. Of more importance is the option to extend the capacities on the Yamal line, which is also commercially attractive. However, by far the strongest impact on the bargaining power is exerted by North Trans Gas, the option to build an offshore pipeline through the Baltic Sea. Although this project cannot compete commercially with the other options to increase transport capacity, it strengthens the Russian position more than all other options together. In a nutshell: competition between Poland and Ukraine is of little strategic importance compared to an option for direct Russian access to customers.

Analyzing bargaining power also helps to understand historic investment patterns and predict future ones, thus explaining the development of the pipeline system over time. As most of the investments in transport facilities are sunk and major players are independent nations, there is substantial risk of opportunistic recontracting. Ukraine, in particular, is considered as a player who cannot credibly commit to adhere to long–term agreements sharing the quasi–rents generated by investment. At the same time the cash–strapped country cannot finance the investment on its own. Although the renovation and upgrading of the system in Ukraine provides a cheap way to increase capacity, the investment has not be undertaken in the past, and, according to our analysis, appears not to be likely in the near future. Our calculations show that expanding facilities in Ukraine would strengthen this country too much in ex–post negotiations to make the project interesting for the other players under the present conditions.

Finally, we 'travel' back to the early nineties when the decision was made to build Yamal, a new alternative route through Poland, at cost which were much higher than what would have been needed for the system in Ukraine. At that time the Russian position was weaker because the option to go offshore for a direct connection was not well developed. Weary of dealing with an already powerful counterpart, Russia was not prepared to further strengthen Ukraine's power. According to our analysis, however, the investment in Ukraine could have been financed even with anticipated recontracting, if the North Trans Gas option were available at that time. This would have strengthened the Russian position in anticipated recontracting enough, making it possible to finance the renovation in Ukraine rather than building new pipelines through Poland. In this sense Ukraine fell victim to a combination of an excessively strong bargaining position and its inability to make credible long–term commitments.

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