Transporting Russian Gas to Western Europe -
A Simulation Analysis

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Abstract

This paper examines the options of transporting Russian gas to Western Europe, an issue that has thus far been dominated by a single transit country, Ukraine. The development of a new transit corridor through Belarus, the so-called Yamal-Europe pipeline, has modified the situation profoundly. The paper develops a model of different strategies of Russia and Ukraine, and derives the analytical solution for Russian gas exports to Western Europe, prices, and the expected profits for the players; we also calibrate numerical results and perform simulations. It turns out that Ukraine suffers a loss from the market entry of Belarus, Russia's profits significantly increase, and Russia has an incentive to expand its gas transit capacity through Belarus further. The gas price for West European importers falls in the case of cooperative behavior of Russia and Ukraine, and/or new pipeline construction through Belarus. However, both developments would also imply a higher European import dependence on Russian gas.

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1 Introduction

The West European dependence upon gas imports from the Soviet Union and, since 1991, from Russia has been and continues to be a critical issue studied from the perspectives of both energy economics and geopolitics. The issue has been dealt with in the literature since the first long-term contracts between Europe and the Soviet Union in the late 1970s (see Greer and Russel, 1982, Banks, 1983). Faced with an increasing demand for gas and decreasing own reserves, the European Union has recently placed gas supply issues at the top of its policy agenda (European Commission, 2000), while putting particular weight on the strategic EU-Russia Energy Dialogue. Not only is Russia's share of EU gas imports expected to increase from the present 40% up to 70%, but Russia is also considered likely to be the swing supplier of gas to Europe for the foreseeable future. Given the expected demand hike for gas in Europe, environmental concerns regarding alternative fuels (mainly coal), the phasing-out of nuclear power, and the dash for gas going on in other regions of the world, the future of Russian gas has become a hot topic far beyond Europe's borders.

The question of how Russian gas reaches the European market has been neglected for some time, since there was no "transit" issue during Soviet times, when Ukraine belonged entirely to the Soviet Union. Since 1991, and through all of the 1990s, Ukraine was the sole transit country upon which Russia had to rely. However, recently, the rules of the game have changed significantly. First, Russia has, in cooperation with Belarus and West European gas importers, completed the parallel pipeline for gas exports via Belarus to Poland and on to Germany, the so-called "Yamal-Europe Pipeline" (see Figure 1). Second, Russia and the West European gas industry have made concrete plans to construct a bypass pipeline from Belarus through Poland to Eastern Slovakia, in order to circumvent the politically unstable Ukraine even further. Third, there is now serious talk about a direct connection between Russia and Germany, the so-called "North Transgas Pipeline" through the Baltic Sea. Thus, the former monolithic gas trade between Russia and Western Europe through Ukraine has become a multi-player game with significant effects on strategies and potential outcomes.

The issue of Russian gas transit to Europe has not received sufficient attention thus far. Stern (1999) assesses the strategy of Russia, and more specifically Gazprom, towards Europe and observes an attempt at diversifying export routes. IEA (2002, 138) observes that Gazprom has encountered transit problems in its exports to Europe, although it confirms high expectations of future Gazprom exports to Europe (rising to about 200 bcm in 2020, against 130 bcm in 2000). Golombek et al. (1995, 1998) analyze the potential effect of liberalizing the gas industry in the supplying countries. They conclude that if the West European gas exporters (Netherlands, Norway, UK) liberalize their markets and split up their monopolistic gas industry, they will win market shares and increase profits, whereas Russia, as a monopolistic supplier through Gazprom, would lose. Conversely, this implies that a liberalization of the Russian gas industry would strengthen Russia's role on the European market even further, and thus require higher transit capacities as well.

An extensive quantitative analysis of interdependence in European East-West gas trade was carried out by Grais and Zheng (1996): using a hierarchical Stackelberg game approach, they show that an improved reliability of gas supply from Russia is beneficial to the Russian gas exporting industry, to the gas transiting countries and to the West European gas importers. More recently, Hubert and Ikonnikova (2003) have modeled the pipeline construction in the Eurasian gas market as a bargaining process between one producer (Russia) and several potential transit countries (Ukraine, Poland, Slovakia). They assume equal bargaining power between producer and transit country and apply a Shapley-value analysis to compare the returns to each of the players from different coalitions. It turns out that a credible option to construct the commercially unviable North Transgas pipeline can strengthen the negotiating power of Russia in negotiations with Ukraine. Hubert and Ikonnikova conclude that, given the low credibility of Ukraine in committing to long-term transit contracts, (foreign) investment in the Ukrainian pipeline system appears not to be likely in the near future, as "expanding facilities in Ukraine would strengthen this country too much in ex-post negotiations to make the project interesting for other players." (p. 28). However, recent developments seem to paint a different picture: in 2003, Russia signed an agreement with Ukraine to enter into a transit pipeline consortium, with the objective of expanding gas exports to Western Europe, and streamlining their policies vis-à-vis the European gas importers. Following that, joint work began in 2004 to expand the transit capacity of natural gas through Ukraine by another 30 bcm. This paper models the options of transporting Russian gas to Western Europe, with a focus on the relations between Russia and Ukraine. We develop different scenarios of Russian gas exports to Europe in the light of potential strategic behavior and pipeline developments in Ukraine and in Belarus. The paper is structured in the following way: Section 2 provides a survey of recent developments in Russian gas exports. The core of the paper is the modeling and subsequent quantification of various development scenarios: Section 3 models the export-transit game between the gas producer (Russia) and the main transiting country (Ukraine), to which we add Belarus as a supplier of additional transit capacity. We model non-cooperative and cooperative strategies for the two- and the three-player game, respectively. Based on the calibration of the model in Section 4, we calculate export volumes, prices, and profits for the participating parties. We also provide results for simulation analyses, the variables being the transit capacity through Belarus, and the West European demand for Russian gas. We find that Russia can gain significantly, both in the cooperative game with Ukraine and from pipeline expansion in Belarus; Ukraine gains from cooperation, but loses significantly after the introduction of a parallel pipeline through Belarus. Western Europe benefits from cooperation between Ukraine and Russia, as well as from expanded pipeline capacity through Belarus, as import prices fall. However, for Europe, this comes at the price of increased import dependence. Section 5 concludes.

2 Recent Developments in Russian Gas Exports and Transit to Western Europe

In spite of the political, economic and social upheaval of the transition crisis in the former Soviet Union, the transport of Russian gas to Central and Western Europe has not only continued but even increased. Russian gas exports to non-CIS countries have increased from 107 bcm (1994) to 132 bcm (2003). The European Commission (2000, 45) expects a further increase of gas imports from Russia of up to 250 bcm by 2020 (i.e. 38% of expected consumption, about 70% of imports); the Russian energy strategy, too, foresees exports outside the CIS of 200-210 bcm by 2020. However, until very recently, the reliability of Russian exports was considered by some observers to be limited due to the political and economic instability in Ukraine, the only available transit country. The dissolution of the Soviet Union and the independence of Ukraine made it possible for the latter to exercise "monopolistic" power in transit. Evidence of this can bee seen in Ukraine's charge of a transit fee of about $0.88-1.09 \frac{US\$}{tcm \cdot 100km}$, whereas its marginal costs were about $0.15-0.24 \frac{US\$}{tcm \cdot 100km}$ (Opitz and Hirschhausen, 2001, 155).[2]

Whereas Russia did not seem to object to Ukraine's dominant role in gas transit in the first half of the 1990s, it seems to have become more concerned with it in the second half of the decade. Subsequently, besides increasing the political pressure on Ukraine,[3] Russia, supported by West European gas importers, tried to create alternative transit capacity to weaken the monopoly power of Ukraine, and to meet additional demand on the West European market via other export routes (see Figure 1):

- New capacities to transport gas through Belarus and Poland were built within the Yamal-Europe-pipeline project, which transports gas from Western Siberia through Belarus (Minsk - Nesvizh) and Poland (Kondratki - Wloclawek) to Germany (Frankfurt/Oder, Mallnow). The connection of the first 56" trunk was completed in November 1999 with a

2 In addition, Ukraine was regularly accused by Russia of illegally withdrawing transit gas. In 2000, Gazprom estimated the gas theft by NaftogazUkrainy at 15 bcm (Infodienst 44/2000, 17); in contrast to this, the Ukrainian government admitted only 8.2 bcm of "unsanctioned removals" of Russian gas (IEA, 2002, 138).

3 Among other things, Russia has required debt-equity swaps for the Ukrainian debt stemming from unpaid energy bills; as of 2003, unpaid bills to Russia amounted to over 1 bn. US$.

nominal capacity of 28 bcm, to which a second (and third) line could be added to carry the capacity to 56 bcm (84 bcm, respectively). Due to lacking compressor capacity along the Belarus and Polish trunk, the capacity was 18 bcm in 2002, a figure that we adopt in the scenarios as base case;

- the next possible step to circumvent Ukraine is the so-called bypass (or: Yamal-2 Pipeline) connecting Kondratki (Poland) to Velke Kapuzany (Slovakia), with a projected annual capacity of 60 bcm. This would allow Russia to export gas via the Central corridor (with its high capacity and convenient connections to West European markets) while still not depending entirely upon Ukraine for transit;
- more recently, the direct undersea pipeline between Vyborg (Russia) and Germany (Peenemuende), the so-called North Transgas pipeline, has attracted much attention. By building this pipeline, Russia would avoid transit of its gas through foreign territory, thus strengthening its export position considerably (Hubert and Ikonnikova, 2003). At this point in time, however, the high costs of the project (up to 20 bn. US$) and the lack of gas in Northwest Russia make the North Transgas pipeline a medium-term rather than a short-term option.[4]

These measures adopted by Russia to curtail Ukraine's strategic importance as a transit country seem to have worked out: in early 2003, Ukraine gave in and accepted a proposal made by Russia to create a joint "gas consortium" and to harmonize their gas export and transit policies. The main objectives of the consortium are to establish the Ukrainian gas-transit system as a reliable, safe and stable delivery option for Russian gas to European markets, and to attract

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[4] Other pipeline projects for Russian gas export exist (e.g. the Blue Stream Pipeline connecting Russia and Turkey through the Black Sea), but they do not affect the constellation analyzed in this paper, and will therefore not be discussed here. For details, see IEA (2002) and Stern (2002).

further investments for the necessary modernization and expansion of the pipeline system.[5] West European gas importers have also shown a strong interest in joining the consortium.

In essence, Russia's efforts to secure greater flexibility and reliability in gas exports have not altered the physical transit business much, since most of the gas still flows through Ukraine. However, it has altered the *strategy space* significantly, and has thus modified the negotiating options of the players. The next section provides a formal approach to modeling these options, which are then quantified in the subsequent section.

3 Modeling the Export-Transit Game

3.1 Non-cooperative versus cooperative solution strategy

Before specifying our model of Russian gas exports to Western Europe through Ukraine and Belarus, we start by identifying the fundamental difference between the two possible strategies – to cooperate or not to cooperate – for the countries involved within a general property. Let x denote the amount of gas transported from Russia through Ukraine to Europe, t the per-unit transit fee charged by Ukraine, and c_R and c_U the constant per-unit costs to Russia and Ukraine, respectively. Furthermore, let us assume that using the pipeline through Ukraine is the only option for transporting Russian gas to Western Europe, and that x_p denotes the corresponding demand function for those gas imports with $x_p \geq 0$ and $\partial x/\partial p < 0$ for all $p \geq 0$, so that the inverse demand function $p = p_x \geq 0$ exists with $\partial p/\partial x < 0$.[6]

5 Under the agreement, Russia and Ukraine set up a new company, which is in charge of transporting Russian gas to the EU; it also has the responsibility to invest in the grid.

6 Considering that the other transit countries to Western Europe (Poland, Hungary, Slovakia, Czech Republic) have already joined the European Union, we do not model their behavior specifically. Neither do we consider the role of Central Asian gas suppliers (Kazakhstan, Turkmenistan) in this

For Russia and Ukraine we define the following two strategies:

- *Non-cooperative strategy*: Russia and Ukraine determine transit quantity (or the final price for gas) and transit tariff independently so as to maximize their respective profits;
- *Cooperative strategy*: Russia and Ukraine determine the profit-maximizing transit quantity (or final price) jointly and share total profits.[7]

Furthermore, we denote:

- $\pi_R(\cdot) = (p - c_R - t)x$ as Russia's profits for the non-cooperative strategy and $x_{nc}^* = arg\,max_{x\geq 0}\{\pi_R(x)\}$ (or $p_{nc}^* = arg\,max_{p\geq 0}\{\pi_R(p)\}$) as solution for Russia's profit-maximization problem;
- $\pi_U(t) = (t - c_U)x$ as Ukraine's profits for the non-cooperative strategy and $t^* = arg\,max_{t\geq 0}\{\pi_U(t)\}$ as solution for Ukraine's profit-maximization problem;
- $\pi_{nc}(\cdot) = \pi_R(\cdot) + \pi_U(t)$ as aggregate profits of the non-cooperative solution;
- $\pi_c(\cdot) = (p - c_R - c_U)x$ as total profits of the cooperative solution and $x_c^* = arg\,max_{x\geq 0}\{\pi_c(x)\}$ (or $p_c^* = arg\,max_{p\geq 0}\{\pi_c(x)\}$) as solution for Russia's and Ukraine's joint profit-maximization problem.

Finally, we assume that profit functions π_R, π_U and π_c are continuous and quasiconcave (so that x_{nc}^* (p_{nc}^*), t^*, x_c^* exist and are unique).

Then:

paper. Furthermore, we do not differentiate between the strategies of the countries (Russia, Ukraine, Belarus) and of the firms (Gazprom, Naftogaz Ukraine, Belarus Gas) at this point.

7 Both strategies are plausible, and have in fact been observed during the past decade, as the countries seem to move from non-cooperative strategies to more cooperation.

Proposition 1: *Profits of the cooperative strategy are always greater than or equal to aggregate profits of the non-cooperative strategy:* $\pi_c^* \geq \pi_{nc}^*$. *Furthermore, the transit quantity (the gas price) in the cooperative strategy is always greater (below) or equal its level in the non-cooperative strategy:* $x_c^* \geq x_{nc}^*$ *(*$p_c^* \leq p_{nc}^*$*).*

Proof: For the non-cooperative strategy, maximum aggregate profits are $\pi_{nc}^* = max_{x\geq 0}\, \pi_R(x) + max_{t\geq 0}\, \pi_U(t) = \left(p_{x_{nc}^*} - c_R - t^*\right)x_{nc}^* + \left(t^* - c_U\right)x_{nc}^* = \left(p_{x_{nc}^*} - c_R - c_U\right)x_{nc}^*$ (or $\pi_{nc}^* = max_{p\geq 0}\, \pi_R(p) + max_{t\geq 0}\, \pi_U(t) = \left(p_{nc}^* - c_R - c_U\right)x_{p_{nc}^*}$). However, because x_{nc}^* (or p_{nc}^*) and t^* are chosen within two separate problems, aggregate profits π_{nc}^* cannot exceed maximum profits for the cooperative solution in which x_c^* is directly chosen to maximize the same expression: $\pi_c^* = max_{x\geq 0}\, \pi_c(x) = \left(p_{x_c^*} - c_R - c_U\right)x_c^*$ (or $\pi_c^* = max_{p\geq 0}\, \pi_c(p) \; = \left(p_c^* - c_R - c_U\right)x_{p_c^*}$).

Next, quasiconcavity of $\pi_U = \left(t - c_U\right)x$ requires that $\partial x / \partial t \leq 0$ or $\partial t / \partial x \leq 0$. Thus, if Ukraine sets $t = c_U$ (zero profits from transit) in the cooperative strategy ($\pi_U = \left(t - c_U\right)x_c^* = 0$) and shares total profits π_c^* with Russia, $\pi_U \geq 0$ for any non-cooperative strategy requires that $x_{nc}^* \leq x_c^*$ (otherwise $t < c_U$) and thus, $p_{nc}^* \geq p_c^*$. q.e.d.

In the subsequent section, we apply this general result to a proper specification and provide simulation analysis with real data.

3.2 Non-Cooperative Strategy (Two Players)

Until 1999, prior to constructing the bypass pipeline through Belarus, Russia transported all of its gas exports to Western Europe through Ukraine. This point of inception can be characterized as follows: Russia, the main supplier of natural gas to Europe, sets an export quantity x to maximize profits $\Pi_R = (p - c_R - t)x$ where $p = p(x)$ is the price for imported (pipeline) gas in Europe with $\partial p(\cdot)/\partial x < 0$, c_R are variable costs and t is the transit tariff set by Ukraine. Furthermore, due to its influential position and bargaining power vis-à-vis Ukraine, Russia is also able to incorporate the best-response function of Ukraine w.r.t. transit tariff $t = t(x)$, where $\partial t(\cdot)/\partial x > 0$. One can justify this structure of the game because Russia's dominant role in the region has repeatedly allowed it to influence political and economic decisions in Ukraine.[8]

The First Order Condition (FOC) for Russia's profit-maximization problem implies that the optimal solution for x satisfies:

$$p(x) + x\left(\frac{\partial p(\cdot)}{\partial x} - \frac{\partial t(\cdot)}{\partial x}\right) = c_R + t \tag{1}$$

Ukraine's problem is to set transit tariff t to maximize profits $\Pi_U = (t - c_U)x$ at given costs c_U. Ceteris paribus, increasing t raises profits. However, since Ukraine has only limited bargaining power Russia punishes it by reducing its transit quantity x in response to an increase in transit fee. Thus, assuming full information, Ukraine's problem is bounded by a function $x = x(t)$ with $\partial x(\cdot)/\partial t < 0$.[9] The corresponding FOC states that the optimal solution for t must satisfy:

$$x + (t - c_U)\frac{\partial x(\cdot)}{\partial t} = 0 \tag{2}$$

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8 For example, this is reflected by the presence of former Gazprom Chairman and Prime Minister Victor Tchernomyrdin as Ambassador to Ukraine, as well as by anecdotic evidence such as quite favorable debt-equity swaps for Ukrainian debts from unpaid energy bills, use of Ukraine's gas-storage facilities at zero-cost by Gazprom until 2001, or the explicit prohibition of Ukrainian gas sales to Europe by Russia as stated in the transit contracts until 2003.

9 Note that this constraint stems exclusively from Ukraine's weak bargaining position vis-à-vis Russia, rather than from time lags, asymmetric information or other reasons.

In the following algebraic specification we assume for simplicity and tractability that the inverse demand function of Western European consumers for imports of natural gas is given by constraint

$$p = ax + b \tag{3}$$

where a <0 and b >0 are exogenous parameters,[10] and that the slope of the best-response function of Russia w.r.t. transit fee t, which measures Russia's bargaining power vis-à-vis Ukraine, is constant:

$$\frac{\partial x}{\partial t} = \sigma < 0 \tag{4}$$

To solve this model we use (4) in equation (2) to receive the best-response function of Ukraine w.r.t. transit quantity x:

$$t = c_U - \frac{1}{\sigma} x \tag{5}$$

Substituting (3) and (5) into (1) we solve for the profit-maximizing transit volume x^* of Russian gas:

$$x^* = \frac{c_R + c_U - b}{2(a + \frac{1}{\sigma})} \tag{6}$$

Finally, using (6) in Ukraine's best-response function the optimal tariff reads

$$t^* = c_U - \frac{c_R + c_U - b}{2\sigma(a + \frac{1}{\sigma})}$$

The logic of this solution is as follows: transit fees set by Ukraine increase with higher transit quantities since (5) increases in x. On the other hand, if Ukraine will face a strong reduction of transit quantities in response to higher transit fees due to its very low bargaining power (that is, if $\sigma << 0$), then it can only charge a modest fee as (5) is increasing in σ ($\sigma < 0$). At the same time, Russia is aware of Ukraine's little bargaining power ($\sigma << 0$) and exports rather large quantities through Ukraine since by equation (6) x is decreasing in σ.

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10 See Section 4.1 for further interpretation of this inverse demand function.

This solution is called *non-cooperative* since it does not consider collusive behavior between Russia and Ukraine. In contrast to this, the following subsection considers a *cooperative strategy*.

3.3 Cooperative Strategy – Nash Product Solution (Two Players)

In the *cooperative strategy*, Russia and Ukraine optimize their joint profit and then distribute this profit between themselves. We assume that surplus is divided according to Nash bargaining. The *Nash product* is the product of each country's profit in case of agreement (cooperative strategy) minus the profit in case of non-agreement (non-cooperative strategy):

$$NP_2 = (\Pi_{R_{coop}} - \Pi_{R_{non-coop}})(\Pi_{U_{coop}} - \Pi_{U_{non-coop}}) \tag{7}$$

where NP_2 stands for the Nash product in the two-player case. If both players cooperate, Russia gets the profit:

$$\begin{aligned} \Pi_{R_{coop}} &= \Pi_R - T_{U_{coop}} \\ &= px - x(c_R + c_U) - T_{U_{coop}} \end{aligned} \tag{8}$$

by compensating Ukraine with a fixed margin $T_{U_{coop}} = x \cdot t$. The profits in the non-cooperative game are those in the situation prevalent until now, i.e. the Ukrainian transit monopoly scenario $\Pi_{R_{Monopoly}}$ and $\Pi_{U_{Monopoly}}$. Hence, the profit maximization function in the Nash-product solution can be written as:

$$NP_2 = (\Pi_R - T_{U_{coop}} - \Pi_{R_{Monopoly}})(T_{U_{coop}} - \Pi_{U_{Monopoly}}) \tag{9}$$

We can now derive the profit maximizing transit fee T^* and from there, derive the optimal export and thus transit quantity. Therefore, we maximize the Nash product (9) w.r.t. $T_{U_{coop}}$, which implies that

$$\frac{\partial NP_2}{\partial T_{U_{coop}}} = -\left(T_{U_{coop}} - \Pi_{U_{Monopoly}}\right) + \Pi_R - T_{U_{coop}} - \Pi_{R_{Monopoly}} \overset{!}{=} 0 \tag{10}$$

and

$$T^* = \frac{\Pi_{U_{Monopoly}} + \Pi_R - \Pi_{R_{Monopoly}}}{2} \tag{11}$$

indicating that Ukraine gets half of the profit-maximizing surplus in the Nash-product solution. Substituting T^* in the Nash-product relation (9):

$$\begin{aligned} NP_2 &= \left(\Pi_R - \frac{\Pi_R - \Pi_{R_{Monopoly}} + \Pi_{U_{Monopoly}}}{2} - \Pi_{R_{Monopoly}} \right) \\ &\cdot \left(\frac{\Pi_R - \Pi_{R_{Monopoly}} + \Pi_{U_{Monopoly}}}{2} - \Pi_{U_{Monopoly}} \right) \\ &= \frac{(ax+b)x - x(c_R + c_U) - \Pi_{R_{Monopoly}} - \Pi_{U_{Monopoly}}}{2} \\ &\cdot \frac{(ax+b)x - x(c_R + c_U) - \Pi_{R_{Monopoly}} - \Pi_{U_{Monopoly}}}{2} \end{aligned} \tag{12}$$

Maximizing (12) w.r.t. x implies:

$$\begin{aligned} \frac{\partial NP_2}{\partial x} &= \frac{(2ax + b - c_R - c_U)}{2} \\ &\cdot \frac{(ax^2 + x(b - c_R - c_U) - \Pi_{R_{Monopoly}} - \Pi_{U_{Monopoly}})}{2} \overset{!}{=} 0 \end{aligned} \tag{13}$$

from which we solve for the profit-maximizing transit quantity:

$$x^* = \frac{c_R + c_U - b}{2a} \tag{14}$$

The optimal export quantity x^* depends only on the player's cost structure and the exogenously given parameters of the demand function (*a, b*). In contrast to the non-cooperative solution (6) it does not depend on the marginal impact of Ukraine's transit fee.[11] Furthermore, as stated by Proposition 1 total profits of Russia and Ukraine in the cooperative solution are never below the sum of their profits of the non-cooperative solution. Nevertheless, the severe

[11] Since $\partial x / \partial t = \sigma < 0$ the optimal solution x^* in (6) is below its level in the cooperative solution (14). This is consistent with Proposition 1.

political-economy-induced problem between Russia and Ukraine still explains why both actors have preferred their non-cooperative strategies for so long. This may also be explained to a certain extent with corporate governance problems (that are not explicitly treated in the model): neither Gazprom nor its Ukrainian counterpart, Naftogaz Ukrainy, are rational profit maximizers, but rather they should be thought of as representing a multitude of principal-agent problems. Conflicts always existed, e.g., between the national governments and the top management, but also within the management itself. These corporate governance issues may have delayed the decision making process further, in particular in Ukraine.

3.4 Non-Cooperative Strategy (Three Players)

We now turn to the three-player game by introducing the "Northern option" of Russian gas exports to Western Europe through Belarus. The role of Belarus in this political process is somewhat inconsistent and difficult to model: on the one hand, Belarus claimed independence of its energy policy, and might thus be modeled as an independent actor with an individual objective function. On the other hand, however, the country not only insisted on an economic union with Russia, but also let Russia carry the entire burden of investing about three bn. US$ in the pipeline extension. We take account of this contradiction by modeling Belarus as a mere provider of transit capacity *without* an individual objective function; the capacity decision itself is made by Russia. Belarus will accept any Russian decision to increase transit capacity since it benefits from it. We define x_U as the quantity, which is transported through Ukraine on the southern route, and x_B as the quantity transiting through the Northern route through Belarus. The total quantity which is transported to Western Europe is then defined as:

$$x = x_U + x_B \tag{15}$$

The new pipeline through Belarus is technically more efficient than the old Ukrainian one which is notoriously outdated, leaky, and has high operation costs. Also, the transport distance along the Northern route to the EU border is shortened by almost 1,000 km. Since the total transport costs from Russia to Western Europe are clearly lower on the Northern route, Russia will prefer to transport gas through Belarus, subject to the prevailing capacity constraint. Ukraine then gets to transport only the residual quantity. Assuming that Belarus is not a self-contained actor and Russia and Ukraine will *not* cooperate, we can calculate the quantity x_U, which will be transported through Ukraine:

$$\Pi_{R_{Monopoly_B}} = p(x_U + x_B) - x_B(c_R + c_B) - x_U(c_R + c_U - \frac{1}{\sigma} x_U)$$

$$\frac{\partial \Pi_{R_{Monopoly_B}}}{\partial x_U} = \frac{2a\sigma(x_U + x_B) + \sigma(b - c_R - c_U) + 2x_U}{\sigma} \overset{!}{=} 0$$

$$\Rightarrow x_U = \frac{c_R + c_U - b - 2ax_B}{2(a + \frac{1}{\sigma})} \qquad (16)$$

Similarly to the non-cooperative solution in the two-player scenario, Ukraine maximizes profits:

$$\Pi_{U_{Monopoly_B}} = (t - c_U)x_U$$

from where we receive its best-response function

$$t = c_U - \frac{1}{\sigma} x_U$$

The solution for this case is similar to the non-cooperative solution for two players (Section 3.2). But Ukraine now receives a lower profit since x_U in equation (16) decreases with increasing x_B (that is with additional lower cost transit capacity) and t decreases with a smaller amount of x_U.

3.5 Cooperative Strategy – Extended Nash Product Solution (Three Players)

We now consider the Nash product solution in the three-player scenario:

$$NP_3 = (\Pi_{Rcoop} - T_{U_{coop}} - \Pi_{R_{Monopoly_B}})(\Pi_{U_{coop}} - \Pi_{U_{Monopoly_B}}) \qquad (17)$$

Russia and Ukraine negotiate a fixed amount $T_{U_{coop}}$ for Ukraine as the global transit fee for the residual quantity. In the cooperative Nash product solution, this corresponds again to half of the profit-maximizing surplus in the Nash product solution, similar to (11). The Nash product can then be calculated as follows:

$$NP_3 = \frac{(ax+b)x - x(c_R + c_U) - \Pi_{R_{Monopoly}} - \Pi_{U_{Monopoly}}}{2} \cdot \frac{(ax+b)x - x(c_R + c_U) - \Pi_{R_{Monopoly}} - \Pi_{U_{Monopoly}}}{2}$$

and we obtain the transit quantity through Ukraine by maximizing w.r.t. x_U

$$\Rightarrow x^*_U = \frac{c_R + c_U - b - 2ax_B}{2a} \tag{18}$$

Note that as for (14) the optimal export quantity x^*_U does not depend on the marginal impact of Ukraine's transit fee and thus exceeds the optimal level in the non-cooperative solution (16). Furthermore, note that the volume x_U that is transported through Ukraine is decreasing in x_B, the capacity on the Northern route through Belarus.

4 Data and Results

4.1 Demand Function and Data

The import demand function $x(p)$ that corresponds to equation (3) can be derived from a nested utility function in which a given consumption level of gas is met by domestic and imported gas and where cost minimization at given prices determines the combination of both. However, since gas imports of Western Europe do not originate from Russia only, the correct linear specification must be $x(p, x_{others})$ where x denotes imports from Russia while x_{others} are imports from all other origins and p is the average price for imported gas in Western Europe (assuming that gas of different importers is sufficiently homogenous, such that imports are solely determined by supply costs and capacity restrictions of the respective pipelines). Consequently, the corresponding form for (3) is

$$p = \alpha \cdot \left(x + x_{others}\right) + \beta \tag{19}$$

where p is the average price for imported gas in Western Europe, and α and β are parameters. Then, if we take changes of other importers to be exogenous in order to focus exclusively on the relation between Russia and Ukraine, this specification coincides with (3) for $a = \alpha$ and $b = \alpha \cdot x_{others} + \beta$. To estimate parameter α and β from (19) we use annual time-series data from 1981 to 2001 for gas imports (sources: BP Statistical Review of World Energy, Eurostat, national statistics) as well as average EU gas import prices (OECD/IEA, var. iss.). For the base scenario, the parameters are $a = -0.789 \frac{US\$}{tcm \cdot 10^9 cm}$, and $b = 141.1 \frac{US\$}{tcm}$).

As regards costs, we use estimates by OME (2002) for all European gas suppliers. Variable transportation costs are taken as 15% of total long-run incremental cost. Thus, Russian production and transit costs to its Western border are $12.3 \frac{US\$}{tcm}$, and marginal transit costs from the Russian border to the EU through Ukraine and Belarus are $5.14 \frac{US\$}{tcm}$ and $4.77 \frac{US\$}{tcm}$, respectively. This confirms that it will be preferable to use the Belarus capacity fully before switching to Ukraine as transit country.

The Ukrainian transit capacities (Central, Progress, and Soyuz) total approximately 130 bcm per year. In 1999 some 60 bcm of gas were transported to Western Europe, and some 40 bcm to Central Europe. Together with exports to countries in the South-East of Europe, the utilization rate of these pipelines was near 100%. The capacity of the Yamal Pipeline via Belarus and Poland is taken as 18 bcm per year during the first stage, and raised to 28 bcm and 56 bcm, respectively, in the scenarios.

4.2 Results: Non-Cooperative Strategy vs. Cooperative Strategy

Tables 1 and 2 provide results of our simulations based on the models developed in the previous section. Both tables include simulations for the non-cooperative and cooperative strategies under various assumptions on the capacity of the Belarus transit pipeline (18 bcm, 28 bcm, and 56 bcm, respectively). Column (1) in Table 1 (base scenario) shows the results for the point of inception, i.e. the period before 1999, with Ukraine as a non-cooperative transit country. For this benchmark, we calibrate the unobservable parameter σ such that our model replicates a quantity of gas exports to Western Europe of 70 bcm as observed in the data, and an initial transit fee charged by Ukraine of $t = 13.7 \frac{US\$}{tcm}$ as derived from OME (2002). Note that under this specification, profits of Ukraine (600 mn. US$) correspond quite closely to independent earlier estimates (see Opitz and Hirschhausen, 2001).

In contrast, column (5) shows the results for the cooperative Nash product solution between Russia and Ukraine (*two*-player game). Note that the profit-maximizing quantity in the cooperative Nash product case has increased to 81 bcm. The difference results from the eliminated mark-up of transit fees by Ukraine, leading to lower prices and therefore increased demand.[12]

Both actors, Russia and Ukraine, benefit from the cooperation, though the increase in profits is modest. The joint profit $\Pi_R + \Pi_U$ is 5.16 bn. US$ (column (5)), as compared to joint profits of 5.07 bn. US$ in the non-cooperative scenario. The additional profit is shared equally between the two countries, so that both Russia and Ukraine are better off by 47 mn. US$ compared to the non-cooperative scenario.

A comparison between columns (1) and (5) of Table 1 also shows that the West European gas importers benefit from the agreement between Russia and Ukraine. While the actual price for gas at the European border amounted to $85.9 \frac{US\$}{tcm}$ in the transit monopoly constellation, it falls to $77.3 \frac{US\$}{tcm}$ in the Nash product solution. As a consequence of the cooperation, Russian gas

12 The parameter σ was calibrated for the year 1998 as -8.13953.

will become more competitive in Western Europe and will therefore - ceteris paribus - obtain a higher market share in Europe.

We now turn to the comparison of strategies in the *three*- player environment, i.e. by taking into account alternative routes from Russia to Western Europe through Belarus. Columns (2)-(4) of Table 1 show the results of the non-cooperative strategy between Russia and Ukraine for different capacities on the Northern route through Belarus (18 bcm, 28 bcm, 56 bcm, respectively). Total gas sales to Western Europe increase (to 72 bcm, 74 bcm, and 78 bcm, respectively). Russian profits rise with increasing capacity through Belarus, a logical result of the lower costs along the Northern route. Ukraine clearly loses transit volumes and profits. Note that the weaker position of Ukraine also leads to a lower mark-up on the transit fee, which falls from $13.7\frac{US\$}{tcm}$ (column (1)) to $7.8\frac{US\$}{tcm}$ (column (4)).

Columns (6)-(8) show the results of the three-player cooperative solution. The assumption here is that the Ukrainian transit charge is reduced to the marginal costs, so that the export quantity is maximized. As could be expected, Russia's export quantities remain the same as in the two player cooperative scenario (81 bcm); as long as the low cost capacities through Belarus are limited, the export quantity is determined by the marginal costs of Ukraine (which are higher than those in Belarus). Note that with increasing capacity through Belarus, the additional profit for Ukraine from pursuing a cooperative strategy diminishes; if Belarus capacity is 56 bcm, Ukraine gets a mere 4 mn. US$ from joining the consortium. We can conclude that cooperation is the first-best solution for both Russia and Ukraine.

Table 1: Result of the data analysis: Base demand scenario

about here

4.3 Simulations with Demand Expansion

We now analyze a scenario where West European demand for Russian gas increases significantly. This scenario is important for two reasons: first, all forecasts point to increased gas demand in Western Europe, which will in turn lead to higher demand for Russian gas (see IEA, 2002, European Commission, 2000). This is due to increased energy demand in Europe, and a fuel switch, away from coal and nuclear power towards natural gas. Second, should this be so, then we are interested in the effect on prices and, eventually, the effect on competition with other gas exporters to Europe (such as Norway and North Africa). We therefore run scenarios on our base model: increased demand for Russian gas in Europe is taken into account by shifting the estimated demand curve upwards: parameter b is set such that total Russian gas exports correspond to the increase of demand ($220 \frac{US\$}{tcm}$).[13] Table 2 presents the results of the demand expansion scenario for the non-cooperative and the cooperative solutions, respectively, in the three-player constellation.

Starting with the non-cooperative scenario, and assuming Belarus transit capacity of 18 bcm (column (1)), total Russian sales to Western Europe will increase significantly, to 121 bcm. Of this, Ukraine will transport 103 bcm to Western Europe, the transit fee would be $17.8 \frac{US\$}{tcm}$, and the Russian gas price in Western Europe would be $134.4 \frac{US\$}{tcm}$, a significant price increase.[14] This scenario confirms that as Belarussian capacity is expanded, Ukraine loses additional transit business. For the scenario of 56 bcm capacity available on the Northern route (column (3)), Ukraine's transit charge decreases to $13.8 \frac{US\$}{tcm}$, and the price for Western Europe falls to $130.4 \frac{US\$}{tcm}$.

Columns (4)-(6) of Table 2 show that in the cooperative strategy, total exports to Western Europe increase to 137 bcm, almost double the 1999 quantity. The total additional surplus arising from the cooperation between producer and transit countries amounts to 204 mn. US$. Extending the Belarussian pipeline system to 56 bcm will increase total profits to 14,977 mn.

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13 Note that we do not take into account strategic behaviour by the other gas exporting countries, such as Algeria and Norway. For such models see Golombek, et al. (1995, 1998), and Perner and Seeliger (2004).

14 Note that we use nominal prices throughout.

US$. It clearly follows that under demand expansion, as well, the cooperative solution is advantageous to both participants.

Table 2: Result of the data analysis: Demand expansion

about here

5 Conclusion

In this paper we have analyzed different options for transporting Russian gas to Western Europe. The issue is increasingly gaining in importance with the opening of a parallel trunk pipeline from Russia to Western Europe through Belarus, and Russian plans to push the diversification of transit routes even further, e.g. the bypass around Ukraine through Slovakia, or the North Transgas Pipeline. The topic is also of high relevance in the emerging European discussion on supply security and the EU-Russian energy dialogue. The issue may even gain in importance; should Russia ponder higher LNG-exports to overseas regions, its pipeline exports to Europe might be adversely affected.

We use a game theory approach to analyze the situation where the transporting country has significant negotiating power since it owns the essential facility, a common situation in international pipeline gas trade. We compare the results of non-cooperative behavior between Russia and Ukraine with the cooperative behavior modeled as a Nash product. The analytical solution to the model confirms the real-world developments observed in the region during recent years: as long as Ukraine was the exclusive transit country, it was unnecessary to think about behaving in a more cooperative way. When Russian efforts to diversify transit routes succeeded, Ukraine changed its strategy and entered into a cooperative agreement with Russia. It may be asked why Ukraine did not reach an agreement with Russia earlier in order to prevent the construction of the new pipeline. Possible and frequently mentioned explanations might be that Ukraine was too self-confident in its monopoly position, short-termism of Ukrainian politicians and gas industrialists, or the substantial distrust of many Ukrainian officials against Russia and the corresponding believe that setting up a cooperative profit sharing scheme is impossible. We have also indicated problems of corporate governance in both countries' gas industries, leading to resource misallocation and suboptimal results.

It has been amply shown that Russia wins from more cooperative behavior by the transit countries because it can raise sales and profits. Note that building up an additional pipeline for exporting gas to Western Europe is a feasible option for Russia only if it can secure long-term contracts to cover the risk of high, sunk investments in the infrastructure. If varying demand and uncertainty drive up the capital costs, it may not be in Russia's interest to invest into new pipeline infrastructure. Deploying a more cooperative strategy vis-à-vis its transit partners, Russia could also increase the feeling of enhanced supply security in Western Europe. As Grais and Zheng (1996) have shown, European demand for Russian gas is positively related to the trust that importers place on the security of supply of these deliveries. Political and economic instability in the main transit country, Ukraine, have indeed for some time raised doubts as to the reliability of supply, thus containing the market share of Russian gas on the West European market.

The implications of the model for the West European gas consumers are complex, too: on the one hand, gas importers clearly benefit from lower prices resulting from cooperation and/or from additional transit capacity through Belarus. On the other hand, European import dependence on Russian gas also clearly increases; in the demand expansion scenario, European imports from Russia almost double. The overall assessment of these developments will then depend upon a political weighing of the objectives of the import-dependent region, between low prices and diversity of supply. In this particular case, the European Commission Green Paper (2000) seems to suggest a proactive strategy of diversification to limit import dependence upon one individual country. Alternative sources of gas supplies to Europe include Norway, the Netherlands, and North Africa (Algeria, Lybia, Egypt), and – in the medium term – also LNG imports from overseas. Most of these alternative countries have wellhead costs below those of Russia, and shorter transport distances to Western Europe. Thus, they are potentially more competitive than Russian gas supply. However, Russia has by far the largest gas reserves, and can therefore expect to gain further market power as its competitors exhaust their reserves. Alternatively, one might also think of an OPEC-like cartel of the gas exporting countries. Indeed, a "Gas Exporting Countries Forum" (GECF) has been established in May 2001 by 11 large gas exporting countries, with the objective of establishing a tangible co-operation among gas producing and exporting countries (see Perner and Seeliger, 2004, for simulations of the effects of a gas cartel on Europe).

The model presented in this paper could be extended in various directions: first, it would be useful to integrate the strategic behavior of other gas exporting countries such as Norway, the Netherlands, and Algeria. Second, a more precise estimation of the European demand function for gas might increase the quality of the empirical results further. In theoretical terms, an open issue is whether the assumed distribution of profits according to the Nash product is appropriate. Last but not least, more complex transit issues can be treated using the approach outlined here, e.g. Caspian energy supplies to Europe.

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Table 1
Result of the data analysis: Base demand scenario

Variables	**Non-Cooperative Strategy** **Ukrainian Transit Monopoly** **Two-Player RUS-UKR**	**Non-Cooperative Strategy** **Extended Ukrainian Transit Monopoly** **Three-Player RUS-BEL-UKR**			**Cooperative Strategy** **Nash Product** **Two-Player RUS-UKR**	**Cooperative Strategy** **Extended Nash Product** **Three-Player RUS-BEL-UKR**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
exogenous:								
x_B (bcm)	-	18	28	56	-	18	28	56
endogenous:								
x (bcm)	70	72	74	78	81	81	81	81
x_U (bcm)	70	54	46	22	81	63	53	24
p (US$/tcm)	85,9	84,0	82,9	79,9	77,3	77,3	77,3	77,3
Π_R (mn US$)	4 468	4 789	4 925	5 215	4 515	4 809	4 945	5 220
Π_U (mn US$)	602	364	257	57	649	392	277	61
Π_R+Π_U (mn US$)	5 070	5 145	5 182	5 272	5 164	5 201	5 222	5 281
t (US$/tcm)	13,7	11,8	10,8	7,8				
NP Russia (mn US$)					47	28	20	4
NP Ukraine (mn US$)					47	28	20	4
Surplus NP (mn US$)					94	56	40	8

Table 2
Result of the data analysis: Demand expansion

Variables	Non-Cooperative Strategy Extended Ukrainian Transit Monopoly Three-Player RUS-BEL-UKR			Cooperative Strategy Extended Nash Product Three-Player RUS-BEL-UKR		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
exogenous:						
x_B (bcm)	18	28	56	18	28	56
endogenous:						
x (bcm)	121	123	126	137	137	137
x_U (bcm)	103	95	56	119	109	81
p (US$/tcm)	134,4	133,3	130,4	121,7	121,7	121,7
Π_R (mn US$)	13 385	13 650	14 276	13 487	13 735	14 323
Π_U (mn US$)	1 307	1 097	607	1 409	1 183	654
$\Pi_R+\Pi_U$ (mn US$)	14 92	14 48	14 83	14 896	14 919	14 977
t (US$/tcm)	17,8	16,8	13,8			
NP Russia (mn US$)				102	85	47
NP Ukraine (mn US$)				102	85	47
Surplus NP (mn US$)				204	171	94

Figure 1
Russian Gas Export Route to Western Europe