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### **Transporting Russian Gas to Western Europe - A Simulation Analysis**

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# Transporting Russian Gas to Western Europe - A Simulation Analysis<sup>1</sup>

**Berit Meinhart, Christian von Hirschhausen, and Ferdinand Pavel**

## 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 (non-cooperative, cooperative Nash-solution, pipeline expansion by Russia elsewhere) 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.

## 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

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<sup>1</sup> This paper is an output from a long-term policy advice program to the government of Ukraine, and a research project on the restructuring of the energy sector in the former Soviet Union; the theoretical analysis was initially based on the Master Thesis of Chollet (2001), who went a long way with us in developing the idea. The authors are indebted to four anonymous referees as well as to Achim Czerny, Katherina Dittmann, Viola Ehrenstein, Dieter Helm, Manfred Horn, Kay Mitusch, Wolfgang Pfaffenberger, and Wolfram Schrettl for comments on this or on earlier versions, and to Anne Neumann and Deborah Bowen for research assistance. Thanks also to seminar audiences at the Carnegie Endowment for International Peace (Washington, D.C., September 2001), DIW Berlin, and to participants of the 25th Annual IAEE International Conference (June 2002, Aberdeen, Scotland), and the 12th Ukrainian-German Economic Symposium (June 2000, Kiev, Ukraine). The usual disclaimer applies.



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 Graph 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 the continental EU-15, 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.

Whereas qualitative and quantitative analyses of Russia as a key supplier of gas to Europe have intensified recently, the issue of 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; but he is cautious on overly optimistic expectations of European gas imports from Russia, since due to large investment requirements and rising production and transport costs, the commercial logic of increasing Russian gas exports to Europe may become questionable (Stern, 1999, 194). IEA (2002, 138) also 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 against 130 bcm in 2000). Golombek et al. (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. But they also conclude that political and economic instability in Russia and in the main transit country, Ukraine, have for some time raised doubts as to the reliability of supply, thus containing the market share of Russian gas on the West European market. More recently, Hubert and Ikonnikova (2003) have modelled 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 early 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-a-vis the European gas importers.

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, to a lesser extent, 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 modelling 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. The base model representing the point of inception is calibrated in Section 4; based on this calibration, 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 gains 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 Russia, 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 137 bcm (2002). The European Commission (2000, 45) expects an 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 be seen in Ukraine's charge of a transit fee of about  $0.88-1.09 \frac{\text{USD}}{\text{bcm} \cdot 100\text{km}}$ , whereas its marginal costs were about  $0.15-0.24 \frac{\text{USD}}{\text{bcm} \cdot 100\text{km}}$  (Opitz and Hirschhausen, 2001, 155).<sup>2</sup>

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,<sup>3</sup> 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 Graph 1):

- New capacities to transport gas through Belarus and Poland were built within the 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 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 2002 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 (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

<sup>2</sup> 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).

<sup>3</sup> Among other things, Russia has named former Gazprom Chairman and Prime Minister Victor Tchernomyrdin as Ambassador to Ukraine. Russia has also required debt-equity swaps for the Ukrainian debt stemming from unpaid energy bills; as of 2002, unpaid bills to Russia amounted to over 1 bn. USD.



capacity and convenient connections to West European markets) while still not depending entirely upon Ukraine for transit;

- more recently, a direct undersea pipeline between Vyborg (Russia) and Germany (Peenemünde), the so-called Nord Stream, 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. USD) make the North Transgas pipeline a medium-term rather than a short-term option.<sup>4</sup>

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

In essence, Russia's strive towards more flexibility in gas exports has 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. While the political configurations in the region may continue to change, the basic patterns are now well understood. The next section provides a formal approach to modelling these patterns, which are then quantified in the subsequent section.

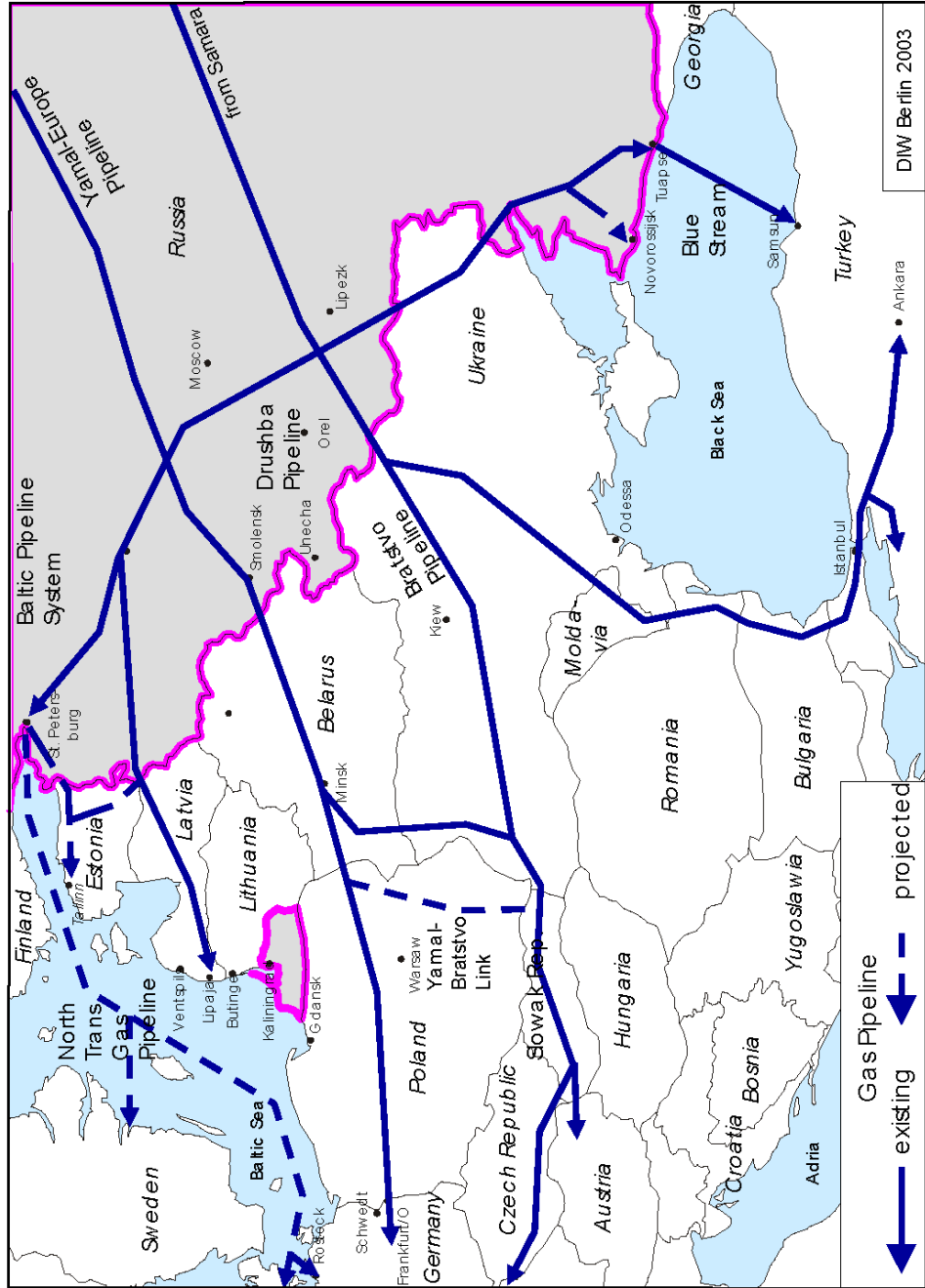
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<sup>4</sup> Other pipeline projects for Russian gas export exist (e.g. the Blue Stream Pipeline connecting Russia and Turkey through the Black sea), but they do not affect the constellation analyzed in this paper, and will therefore not be discussed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

<sup>5</sup> Under the agreement, Russia and Ukraine set up a new company which is in charge of transporting Russian gas to the EU; it has the responsibility to invest in, and eventually extend, the grid. The contract stipulations on profit sharing are confidential, but it is fair to assume that both parties will improve their position by participating in the consortium.



**Graph 1**  
Russian Gas Export Route to Western Europe





### 3 Modelling the Export-Transit Game

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. For simplicity, we concentrate on the relation between Russia and Ukraine, the main countries involved.

#### 3.1 Non-cooperative versus cooperative solution strategy:

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  $\partial p / \partial x < 0$ .<sup>6</sup>

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.

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;

<sup>6</sup> Considering the other transit countries to Western Europe (Poland, Hungary, Slovakia, Czech Republic) are already becoming part of the enlarged Europe, we do not model their behavior specifically. Neither do we consider the role of Central Asian gas suppliers (Kazakhstan, Turkmenistan) in this 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.



- $\pi_U(t) = (t - c_U)x$  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  $\pi_R$ ,  $\pi_U$  and  $\pi_c$  are continuous and quasiconcave (so that  $x_{nc}^*$  ( $p_{nc}^*$ ),  $t^*$ ,  $x_c^*$  exist and are unique).

Then:

**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  $\pi_{nc}^* = \max_{x \geq 0} \pi_R(x) + \max_{t \geq 0} \pi_U(t) = (p_{x_{nc}^*} - c_R - t^*)x_{nc}^* + (t^* - c_U)x_{nc}^* = (p_{x_{nc}^*} - c_R - c_U)x_{nc}^*$  (or  $\pi_{nc}^* = \max_{p \geq 0} \pi_R(p) + \max_{t \geq 0} \pi_U(t) = (p_{nc}^* - c_R - c_U)x_{p_{nc}^*}$ ). However,

because  $x_{nc}^*$  (or  $p_{nc}^*$ ) and  $t^*$  are chosen within two separate problems, aggregate profits  $\pi_{nc}^*$  can not exceed maximum profits for the cooperative solution in which  $x_c^*$  is directly chosen to maximize the same expression:  $\pi_c^* = \max_{x \geq 0} \pi_c(x) = (p_{x_c^*} - c_R - c_U)x_{x_c^*}^*$  (or  $\pi_c^* = \max_{p \geq 0} \pi_c(p) = (p_c^* - c_R - c_U)x_{p_c^*}^*$ ).

Next, quasiconcavity of  $\pi_U = (t - c_U)x$  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 ( $\pi_U = (t - c_U)x_c^* = 0$ ) and shares total profits  $\pi_c^*$  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 – Ukrainian Transit Dominance (Two Player RUS-UKR)

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 a leader-follower constellation between Russia and Ukraine: Russia, the leader, has full information on costs and demand. It sets a profit-maximizing export quantity subject to the inverse demand function of West European consumers as well as on the corresponding transit tariff set by Ukraine. In turn, Ukraine, the follower, sets a tariff in order to maximize its profits from transporting gas subject to its conjectures concerning Russia's export decision.

More formally, Ukraine's profit-maximization problem is:

$$\max_{t \geq 0} \Pi_U = \max_{t \geq 0} (t - c_U)x \quad (1)$$

$$\text{s.t. } \frac{\partial x}{\partial t} = \sigma < 0 \quad (2)$$

where  $t_U$  is the specific transit charge (per 1,000  $m^3$  of gas,  $c_U$  characterizes Ukraine's marginal costs of transport, and  $\sigma$  denotes Ukraine's conjectures concerning Russia's export decision when Ukraine changes its tariff.  $\sigma$  is negative since Ukraine expects Russia to reduce its export quantity if Ukraine raises its tariff.<sup>7</sup> For simplicity and tractability, we assume this conjecture to be constant.

From the FOC of (1) we find the profit-maximizing transit tariff  $t$  to be:

$$t = c_U - \frac{1}{\sigma}x \quad (3)$$

As stated above, Russia's problem is to take its costs  $c_R$  as given and to choose exports  $x$  to

$$\max_{x \geq 0} \Pi_R = \max_{x \geq 0} (p - c_R - t)x \quad (4)$$

subject to the transit fee set by Ukraine (3) as well as the inverse demand function of Western European consumers for imports of natural gas, which - as further simplification - is taken to be linear:

$$p = ax + b \quad (5)$$

<sup>7</sup> Given its position as transit monopoly, Ukraine could in theory also request almost the entire rent from gas exports to Europe and leave only a minimal amount to Russia. However, anecdotal evidence, such as the zero-cost use of Ukraine's gas-storage facilities by Gazprom until 2001, or the explicit prohibition of Ukrainian gas sales to Europe by Russia as stated in the transit contracts, demonstrates that Ukraine has never had such a bargaining position.



where  $p$  is the price for imported (pipeline) gas in Europe,  $x$  the quantity which is imported by Russia, and  $a < 0$  and  $b > 0$  are the exogenous parameters.<sup>8</sup> Integrating (3) and (5) into (4) and taking the FOCs we derive Russia's profit-maximizing export quantity to Western Europe:

$$\begin{aligned} \frac{\partial \Pi_R}{\partial x} &= 2ax + b - c_R - c_U + \frac{2}{\sigma}x = 0 \\ \Leftrightarrow x &= \frac{c_R + c_U - b}{2(a + \frac{1}{\sigma})} \end{aligned} \quad (6)$$

The logic of this equilibrium is as follows: transit fees set by Ukraine increase with higher transit quantities since (3) increases in  $x$ . On the other hand, if Ukraine conjectures a strong reduction of transit quantities in response to higher transit fees (that is, if  $\sigma \ll 0$ ), then it charges a modest fee only as (3) is increasing in  $\sigma$  ( $\sigma < 0$ ). In contrast, if Russia knows that Ukraine has such conjectures ( $\sigma \ll 0$ ), then (7) indicates that it exports rather large quantities through Ukraine because  $x$  is decreasing in  $\sigma$ . This scenario 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 Player RUS-UKR)

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):

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

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

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

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:

<sup>8</sup> See Section 4.1 for further interpretation of this inverse demand function.



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

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

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

and

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

indicating that Ukraine gets half of the profit-maximizing surplus in the Nash-product solution.

Substituting  $T^*$  in the Nash-product relation (9):

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

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

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

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

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

The optimal export quantity  $x^*$  depends only on the player's cost structure and the exogenously given parameters of the demand function ( $a$ ,  $b$ ). Comparing export quantities in the non-cooperative solution (6) with the cooperative solution (14), the former is below the latter since  $\sigma < 0$ .



Furthermore, total profits of Russia and Ukraine in the cooperative solution are never below the sum of their profits of the non-cooperative solution.

### 3.4 Non-Cooperative Strategy – Extended Ukrainian Transit Monopoly (Three Player RUS-BEL-UKR)

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 modelled 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. USD in the pipeline extension. We take account of this contradiction by modelling 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.<sup>9</sup> 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:

$$x = x_U + x_B \quad (15)$$

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 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:

$$\Pi_{R_{Monopoly_B}} = p(x_U + x_B) - x_B(c_R + c_B) - x_U(c_R + c_U - \frac{1}{\sigma}x_U) \quad (16)$$

$$\frac{\partial \Pi_{R_{Monopoly_B}}}{\partial x_U} = \frac{2a\sigma(x_U + x_B) + \sigma(b - c_R - c_U) + 2x_U}{\sigma} = 0 \quad (17)$$

$$\Rightarrow x_U = \frac{c_R + c_U - b - 2ax_B}{2(a + \frac{1}{\sigma})} \quad (18)$$

<sup>9</sup> If we wanted to introduce Belarus as an independent actor, we would need to recur to a Shapley value analysis to solve this three-player negotiation process, as has been suggested by Hubert and Ikonnikova (2003).



Similarly to the non-cooperative solution in the two-player scenario (1), Ukraine obtains the following profit:

$$\Pi_{U_{Monopoly_B}} = (t - c_U)x_U \quad (19)$$

### 3.5 Cooperative Strategy – Extended Nash Product Solution (Three Player RUS-BEL-UKR)

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

$$NP_3 = (\Pi_{coop} - T_{U_{coop}} - \Pi_{R_{Monopoly_B}})(\Pi_{U_{coop}} - \Pi_{U_{Monopoly_B}}) \quad (20)$$

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:

$$NP_3 = \frac{(ax + b)x - x(c_R + c_U) - \Pi_{R_{Monopoly}} - \Pi_{U_{Monopoly}}}{2} \cdot \frac{(ax + b)x - x(c_R + c_U) - \Pi_{R_{Monopoly}} - \Pi_{U_{Monopoly}}}{2} \quad (21)$$

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

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

Note that the distortionary mark-up characterized by  $\sigma$  has disappeared, implying that the transit quantities are higher than in the non-cooperative scenario. Logically, 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 (5) 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 (5) is

$$p = \alpha \cdot (x + x_{others}) + \beta \quad (23)$$

where  $p$  is the average price for imported gas in Western Europe, and  $\alpha$  and  $\beta$  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 (5) for  $a = \alpha$  and  $b = \alpha \cdot x_{others} + \beta$ . To estimate parameter  $\alpha$  and  $\beta$  from (23) 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  $a = -0.789 \frac{USD}{tcm \cdot 10^9 cm}$ , and  $b = 141.1 \frac{USD}{tcm}$ .

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  $12.3 \frac{USD}{tcm}$ , and marginal transit costs from the Russian border to the EU through Ukraine and Belarus are  $5.14 \frac{USD}{tcm}$  and  $4.77 \frac{USD}{tcm}$ , respectively; therefore, it will be preferable to use the Belarus capacity fully before switching to Ukraine as transit country.

The Ukrainian transit capacities (Belarus, Progres, and Sojuz) 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  $\sigma$  from equation (2) 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  $t = 13.7 \frac{USD}{tcm}$  as derived from OME (2002). Note that under this specification,



profits of Ukraine (600 mn. USD) 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.<sup>10</sup>

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. USD (column (5)), as compared to joint profits of 5.07 bn. USD 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. USD 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  $85.9 \frac{\text{USD}}{\text{bcm}}$  in the transit monopoly constellation, it falls to  $77.3 \frac{\text{USD}}{\text{bcm}}$  in the Nash product solution. As a consequence of the cooperation, Russian gas 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  $13.7 \frac{\text{USD}}{\text{bcm}}$  (column (1)) to  $7.8 \frac{\text{USD}}{\text{bcm}}$  (column (4)).

<sup>10</sup> The parameter  $\sigma$  was calibrated for the year 1998 as -8.13953.



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

Variables	Non-Cooperative Strategy		Non-Cooperative Strategy		Cooperative Strategy		Cooperative Strategy	
	Ukrainian Transit Monopoly		Extended Ukrainian Transit Monopoly		Nash Product		Extended Nash Product	
	(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
$p$ (USD/tcm)	85,9	84,0	82,9	79,9	77,3	77,3	77,3	77,3
$\Pi_R$ (mn USD)	4 468	4 789	4 925	5 215	4 515	4 809	4 945	5 220
$\Pi_U$ (mn USD)	602	364	257	57	649	392	277	61
$\Pi_R + \Pi_U$ (mn USD)	5 070	5 145	5 182	5 272	5 164	5 201	5 222	5 281
$t$ (USD/tcm)	13,7	11,8	10,8	7,8				
NP Russia (mn USD)					47	28	20	4
NP Ukraine (mn USD)					47	28	20	4
Surplus NP (mn USD)					94	56	40	8



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 Ukraine). 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. USD from joining the consortium. We can conclude that cooperation is the first-best solution for both Russia and Ukraine.

### 4.3 Simulations with Demand Expansion

We now analyze a scenario where West European demand for Russian gas increases significantly. 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). We incorporate the shift in demand for Russian gas by shifting the estimated demand curve upward: parameter  $b$  is set such that total Russian gas exports correspond to the increase of demand ( $220 \frac{USD}{tcm}$ ). 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  $17.8 \frac{USD}{tcm}$ , and the Russian gas price in Western Europe would be  $134.4 \frac{USD}{tcm}$ , a significant price increase. 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  $13.8 \frac{USD}{tcm}$ , and the price for Western Europe falls to  $130.4 \frac{USD}{tcm}$ .

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. USD. Extending the Belorussian pipeline system to 56 bcm will increase total profits to 14,977 mn. USD. The important result is that under demand expansion, as well, the cooperative solution is advantageous to both participants.



**Table 2**  
Result of the data analysis: Demand expansion

Variables	Non-Cooperative Strategy			Cooperative Strategy		
	Extended Ukrainian Transit Monopoly			Extended Nash Product		
	Three-Player RUS-BEL-UKR			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
$p$ (USD/tcm)	134,4	133,3	130,4	121,7	121,7	121,7
$\Pi_R$ (mn USD)	13 385	13 650	14 276	13 487	13 735	14 323
$\Pi_U$ (mn USD)	1 307	1 097	607	1 409	1 183	654
$\Pi_R + \Pi_U$ (mn USD)	14 92	14 48	14 83	14 896	14 919	14 977
$t$ (USD/tcm)	17,8	16,8	13,8			
NP Russia (mn USD)				102	85	47
NP Ukraine (mn USD)				102	85	47
Surplus NP (mn USD)				204	171	94

## 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.



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 modelled 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. Assuming Russia would extend the pipeline capacity on the northern route to 56 bcm, Ukraine would yield only a tenth of the profits it gained before the Belorussian pipeline was established. One explanation may be that Ukraine was too self-confident in its monopoly position; another interpretation is short-termism of Ukrainian politicians and gas industrialists.

It has been amply shown that Russia wins from more cooperative behavior by the transit countries because it can raise sales and profits. Russia also stands to gain from a "soft" aspect of this cooperation, i.e., an increased sense of supply security in Western Europe (Grais and Zheng, 1996). The implications of the model for the West European gas consumers are more complex: 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.

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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