Master thesis for Economics

Transporting Russian gas to Western Europe:

A comparison between non-cooperative and cooperative game approach

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TABLE OF CONTENTS

1. Introduction

1.1 Motivation and research question

As an attractive source of energy, natural gas contributes to the diversification and securing of overall energy supply to Europe. It is environment-friendly with low carbon dioxide emission and serves as a primary substitute for coal and oil. However, the declining domestic gas production within the Europe cannot catch up with the rocketing demand. As a result, import plays a vital role in the gas supply for Europe. In 2002, 40% of natural gas consumed in the Central and Western Europe countries was covered by outside producers, among which Russia dominates the market with a share of 19%, other importers were Norway (10%), Algeria (11%) and other African Liquefied Natural Gas (LNG) suppliers (1.5%) (Ikonnikova, 2005). By 2015 over 65% of the total gas consumption will be supported by external producers (Ikonnikova, 2006). Therefore, considering the importance of gas as a source of energy consumption, together with Europe's increasingly independence on outside producers, the impact of gas suppliers' strategic behaviors on gas import in Europe deserves more attention in academic field.

As a kind of liquid in most transporting conditions, the gas exported to Europe from Russia needs to be delivered through a network of pipelines. The pipelines are constructed in the territories of both Russia and other transit countries. A transit country does not produce natural gas by itself; instead it charges a transit tariff and makes profit from transporting gas from the country where the gas is explored. Therefore basically there is a vertical relationship between the producing country and the transit country. However sometimes the two sides cannot reach to an agreement on the transit tariff, or there may exist political conflicts which jeopardizes their relations as partners in the gas supply chain. We refer to these disagreements as transit issues. The gas delivered to the European market from Russia is mainly passing through Ukraine. Since Ukraine was part of the Soviet Union before 1991, there was no transit issue during Soviet times. After that Ukraine has been the sole transit country of Russian natural gas for about a decade from 1991 till 2000. However there were constant disagreements between the two countries through the nineties over issues like the fees for transit service, the price for Ukraine’s gas import, payment delays and debts, Ukraine’s re-export of Russian gas etc. Although the two countries made new attempts to lay down principles for their gas relations in the past decade (in 2001, there appears a number of agreements addressed transit fees, prices and quantities for Ukraine’s own gas imports from Russia, and the settlement of controversial debts resulting from payment.), the deterioration of the bilateral situation seemed to aggregate. In January 2009, conflicts escalated to the point where supplies on the major transit route were completely cut off for two weeks.

In order to secure greater flexibility and reliability in gas exports, Russia made large efforts to diversify export routes ever since the early nineties. In 1998, a new export corridor through Belarus and Poland, now commonly referred to as *Yamal 1*, went into operation. This alternative transit line improved Russia’s strategic advantage and weakened Ukraine’s monopolistic power. However, like Ukraine, Belarus leveraged its newly gained strategic position in the transportation route to gain benefit for its own gas imports. These disagreements led, not surprisingly, to the plans for an offshore pipeline to Western Europe. In late 2005, Russia and Germany signed a treaty to build a huge new pipeline, later named *Nord Stream*, through the Baltic Sea. So far, the first of Nord Stream's two parallel pipelines has become operational in November 2011. The second line has already been laid and is expected to come on stream on schedule in the last quarter of 2012. Although so far the cost and technological risk of this line are the largest among all possible delivering networks, only the possibility of such an outside option is anticipated to significantly improve Russia’s bargaining power with transit countries (Hubert and Ikonnikova, 2011).

As a consequence of these new transit options, a re-consideration of the relations between Russia and transit countries becomes necessary. Two ways of modeling the Russian gas supply chain have been found in recent literature. Hirschhausen et al. (2005) designed different scenarios of transporting Russian gas to Western Europe using non-cooperative game theory. First, they investigated the profit-maximization behavior of the two countries when there is no other transit bypass. Then their strategies were compared adding Belarus as a supplier of additional transit capacity.

On the other hand, Hubert and Ikonnikova (2011) examined the effect of investment options on bargaining power in the cooperative game paradigm. Yet few literatures have made comparisons about the two approaches (non-cooperative game approach and cooperative game approach) on their possible different effects. The present paper makes its contribution in trying to compare the two different approaches. Here by “non-cooperative game approach” we mean the strategic behavior of players which aims at maximize own profit; while “cooperative game approach” is the formation of a coalition and enforcement of coordinated behavior. In the present paper, we define the two possible approaches as follows. If the players act in a non-cooperative game approach, Russia and the transit country would determine the transit capacity and the transit tariff independently in order to maximize their own profit. Whereas, should cooperative game solution be the situation, both countries determine the profit-maximizing transit capacity jointly and share total profit based on certain rules. In the present paper, we regard “the cooperative game approach” “cooperation” and “coalition” as identical concepts. Considering the current situation of diverted transportation investments, if a better understanding can be achieved on how these two approaches (non-cooperative and cooperative) will affect the equilibrium export quantity and profit distribution under the condition of new investment options, it might help the countries in the Russian gas supply chain to re-examine their relationship and to act in a more rational way. It also helps to predict the Eurasian gas delivery network developments and the securing of gas supply to Europe in the future.

Hence, the research question of the present paper is:

To compare the non-cooperative game approach and cooperative game approach within the Russian gas supply chain about their effects on export volumes, prices and profits allocations for the participating parties under the condition of new investment options.

1.2 Methodology

The present paper will model the transportation of Russian natural gas using both non-cooperative and cooperative game theory. We will explore different players' profit maximizing process. Variables including export quantities, prices, cost structure and transit tariff will be set according to the two possible solutions. The effect of new investment on equilibrium transit quantity and profit allocation will be analyzed and compared.

Two scenarios are put forward: in the first scenario Ukraine is regarded as the monopolistic transit country of Russian gas; in the second scenario Russia invests in the offshore pipeline *Nord Stream* as a transit bypass. As is defined in the previous part, two approaches are considered: Russia and Ukraine act independently or cooperatively. The two possible situations will be modeled in each scenario, and comparisons will be made about their effects on Ukraine's transit volumes. Besides the profit distribution under cooperation will also be discussed.

1.3 Structure

The present paper includes five parts. After a short introduction, recent research is reviewed on the transportation of Russian gas, non-cooperative and cooperative game solutions for the transit game and double marginalization. Part 3 models the export-transit game between Russia and Ukraine based on two scenarios. In scenario 1, Russia can deliver the natural gas only through Ukraine. In scenario 2, Russia invests in the *Nord Stream* as a bypass. In both scenarios, non-cooperative and cooperative strategies will be modeled, and comparisons will be made about their effects on export volumes, prices and profits divisions between the two countries. Part 4 presents the results of a simple simulation. Part 5 concludes.

2. Literature review

We first review the literature on the strategic relations between different parties in the Russian gas supply system. Grais and Zheng (1996) make a quantitative analysis of the strategic interaction in the Eurasian gas supply chain. By giving Russia a first mover advantage, they assume that it has all the bargaining power and has the ability to extract the whole rent. Different from their analysis, the present paper tries to derive the bargaining power endogenously from the architecture of the transmission system based on the Shapley value using cooperative game theory. Besides, Russia can only charge linear prices in their model, whereas we assume a two-part tariff in our game settings. Using a coalition bargaining game model, Ikonnikova (2005) explores endogenous strategic coalition formation and its impact on investment decision-making. When making investment decisions, the members of the supply chain (producers and transiters) have to consider possible future cooperation. After the investments are sunk, the players bargain about allocation of rents within the capacity constraint. However for some players (usually the transit countries), their credible commitment to stick to the predetermined profit sharing cannot be assured at this stage. Therefore renegotiation becomes necessary after the capacities are installed. Hence there is a hold-up problem in the investment decision. In her followed paper in 2006, Ikonnikova continues her study about the hold-up problem and finds out that Russia overinvests in the expensive direct Baltic route in order to gain the bargaining advantage over Ukraine and Byelorussia. On the other hand, Turkmenistan, the other producer in this game, tends to initiate the bypass along Iran or Azerbaijan so as to compete with Russia. Yet, if both the producers can cooperate, only Baltic pipeline will be built. Li and Sick (2010) examine the equilibrium of a real options bargaining and exercise game using evidence from the natural gas industry. Their outcomes show a negative effect of the real option exercise price on the probability of cooperation, which forms a reverse discussion to our conclusion that cooperation leads to lower prices.

Our analysis shows that cooperation between Russia and Ukraine can solve the double marginalization problem, a concept proposed by Spengler in 1950. In his study he considers a vertical structure consisting of a manufacturer and a retailer. In the vertically integrated situation, the equilibrium quantity and retail price is determined by the demand function. In the decentralized situation, the manufacturer chooses a linear tariff first and the retailer chooses the retail price second. He infers that the retail price is larger than the vertically integrated equilibrium price as long as the manufacturer charges above its marginal cost. The higher price in the decentralized structure comes from the two successive mark-ups (marginalization). Tirole (1987) concludes Spengler's model as one of the illustrations for vertical externality. He argues that the decisions made by a retailer to increase his demand for the intermediate good generate a positive marginal profit for the manufacturer. However, the retailer does not take the manufacturer's incremental profit into account. Therefore, when maximizing his own profit, he tends to make decisions that lead to too low a consumption of the intermediate good. The aggregate profit is then lower than the vertically integrated one, which motivates the manufacturer to impose vertical restrains that eliminate this externality. In our game setting, Russia has to buy the complementary transit pipeline to export its natural gas. Therefore, Ukraine, offering the complementary pipelines, acts as the manufacturer in the vertical structure and charges a transit fee larger than its marginal profit. The transit fee charged by Ukraine is considered by Russia as a part of its marginal cost when making decisions on the optimized export volume. Consequently, the export quantity is lower when the two countries do not cooperate (which is equivalent to a decentralized vertical structure) because of their sequential mark-ups. Armstrong (2002) analyzed the double marginalization problem in telecommunication industries. If two countries determine the international call termination fees non-cooperatively, it will lead to very high level charges due to the standard double marginalization problem. If the two countries negotiate mutual termination charges, the problem can be avoided. Armstrong's analysis of double marginalization in telecommunication industry is very similar to our conclusion that cooperation can solve this problem in Russia gas supply chain.

The present paper can also be related to the large literature on collusion in oligopoly. Nocke (2007) examines a repeated duopoly with irreversible investment in product quality. In his study firms tend to reduce quality under collusion in comparison with the non-cooperative case, which corresponds to overinvestment for increasing bargaining power in our game settings. As another contribution in this field, Feuerstein and Gersbach (2003) study irreversible investment in Cournot duopoly. They show that in cournot equilibrium all players overinvest in contrast with the profit-maximizing capacities. Although collusion can be supported by the threat of delayed investment, the punishment is less effective because the deviating firm enjoys a first mover advantage when capacities are irreversible.

In our analysis we conclude that consumers in Europe benefit from Russia and Ukraine's cooperation as a result of reduced price and increased export volume. Nevertheless, the situation also raises the concern of European countries' dependence on Russia gas supply. Morbee (2007) discusses this problem based on Russia's market power on the EU gas market. After performing a partial equilibrium model, he concludes that Russian market power is limited since European demand is elastic even in the short run. Moreover, as Russia's default probability increases, consumers in Europe prefer to import gas from more reliable suppliers at an appropriate price premium, despite Russia's larger storage capacity. Finon and Locatelli (2007) also confirm that it is not necessary to create a special power at the European level aiming at guarding all costs against the risk associated with the Russian seller's market power. The long-term contracts market is fundamentally a contestable market. Besides, the gas trading between Russia and Europe is determined by market principles. Russia also need stable long-term contractual arrangements based on credible commitments.

3. The model

We propose a dynamic game to model the actions of transporting Russian gas to the European countries, with a focus on the relation between Russia and Ukraine. Two players are involved in this game: Russia and Ukraine. Two sets of situation are considered. In the first set of situation, Russia transports all its gas through Ukrain or invests in new pipelines instead of relying on Ukraine as the monopolistic transit country. We abstract from the effects of other bypasses including *Yamal 1*, *Yamal 2* and *Baltic*, and focus on the offshore network *Nord Stream,* which connects Russia and the European consumers directly once built. The second set of actions is that both players act in non-cooperative game approach or in a cooperative game approach. In the situation of independent decision-making, Russia will determine the transit volume, and Ukraine the transit tariff each maximizing its own profit. Whereas, should cooperative game approach be the situation, both countries act as an coalition and determine the profit-maximizing transit quantity jointly and share total profit based on the Shapley value. In the present paper, we regard "the cooperative game approach" "coalition" and "cooperation" as identical concepts.

The Shapley value is the player's expected payoffs from a coalition. The incremental value a new player brings to the coalition is equally shared between all players. In our game setting, the incremental rent brought by Ukraine to the cooperation will be evenly split to Russia and Ukraine. So the Shapley value for Russia and Ukraine, denoted by φ_R and φ_U respectively, in the cooperation is:

$$\varphi_R = v(R) + \frac{1}{2}(v(RU) - v(R)) \tag{1}$$

$$\varphi_U = \frac{1}{2}(v(RU) - v(R)) \tag{2}$$

$v(\cdot)$ is the value function, representing the total profit obtained if only the players in the brackets cooperate. The value function captures the essential economic and institutional features, including geography of the network, different cost of alternative pipelines, demand for gas, production cost, etc. (Hubert and Ikonnikova, 2011).

Furthermore, two assumptions are made. First, let us assume that using the pipeline through Ukraine is the only option for transporting Russian gas to Western Europe before *Nord Stream* is built, and *Nord Stream* is the only option for Russia to invest beside the Ukraine pipeline. Secondly, there is no demand expansion of European gas import.

There are two scenarios in our model. The first one is that Russia can transport gas only through Ukraine. We will analyze how they determine the export quantity and transit tariff when the two distinct approaches: non-cooperative game approach and cooperative game approach are used. The second scenario shows the situation that Russia invests in *Nord Stream* as a bypass besides Ukraine. The effects of both independent strategy and cooperation on the determination of export quantity and transit tariff will be discussed. Also comparisons will be made about the two scenarios on how profits are split between the two players in cooperation.

3.1 Scenario one: monopolistic transit through Ukraine

When Ukraine is the only possible transportation network, Russia exports all its gas through Ukraine. Let x denote the amount of gas transported from Russia through Ukraine to Europe, s the per-unit transit fee charged by Ukraine. c_R signifies the constant per-unit cost of Russia transporting gas to its western border, while c_U stands for the constant per-unit cost of Ukraine. The demand function for European gas import is assumed to be $x(p)$ with $x(p) \geq 0$ and $\frac{\partial x}{\partial p} < 0$ for all $p \geq 0$, so that the inverse demand function $p = p(x)$ exist with $\frac{\partial p}{\partial x} < 0$. We assume for simplicity that the inverse demand function of European consumers for imports of natural gas is given by linear function:

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

Where $a > 0$ and $b > 0$ are exogenous parameters and independent of the time period.

As a benchmark, we give a short description of the outcome when the market is perfectly competitive. In this situation, Ukraine only charges a per-unit transit fee equal to its marginal cost, which is $s = c_U$. Ukraine makes no profit from transporting Russian gas because of the competitiveness of other transit countries (assuming there are many possible transit countries). Russia, as the only upstream supplier, obtains all the profit in its gas supply chain.

3.1.1 non-cooperative game approach

If non-cooperated game approach is adopted in this bilateral monopoly situation, the interaction between Russia and Ukraine is modeled as a two-stage game. In the first stage, Ukraine sets the marginal transit tariff s to maximize its profit:

$$\pi_U = (s - c_U) \cdot x$$

In the second stage, Russia, the main supplier of natural gas to Europe, sets an export quantity x to maximize its own profit subject to the resource constraint. Suppose the total exploitable reserve of natural gas in Russia is denoted by $\bar{X}$, then Russia's optimization problem is:

$\max \pi_R = (p - c_R - s) \cdot x$

$\mathrm{s.t.}\, 0 \leq \ x \leq \bar{X}$

Where $p = p(x)$ is the price for imported gas in Europe with $\frac{\partial p}{\partial x} < 0.$

The two-stage game is solved by backward induction. The Lagrange function for Russia's optimization problem is

$\mathrm{L} = (p - c_R - s) \cdot x + \lambda(\bar{X} - x)$

The Kuhn-Tucker Conditions for this optimization problem are:

$\frac{\partial L}{\partial x} = \frac{\partial p}{\partial x} \cdot x + (p - c_R - s) - \lambda \leq 0$

$x \geq 0$

$x \cdot \frac{\partial L}{\partial x} = 0$

$\frac{\partial L}{\partial \lambda} = \bar{X} - x \geq 0$

$\lambda \geq 0$

$\lambda \cdot \frac{\partial L}{\partial \lambda} = 0$

Since there is very little possibility for Russia to export all the natural gas for one period, we can derive that

$x < \bar{X}\,, \quad \Longrightarrow \quad \frac{\partial L}{\partial \lambda} > 0, \quad \Longrightarrow \quad \lambda = 0$

And we assume that Russia must explore some positive quantity of natural gas in one period, which implies

$$x > 0, \quad \Longrightarrow \quad \frac{\partial L}{\partial x} = \frac{\partial p}{\partial x} \cdot x + (p - c_R - s) = 0, \quad \Longrightarrow \quad \frac{\partial p}{\partial x} \cdot x + p = c_R + s \tag{4}$$

So Russia sets the optimized quantity by equalizing marginal revenue to marginal cost. And the optimized export quantity of natural gas is solved as:

$$x = \frac{b - c_R - s}{2a} \tag{5}$$

The first order condition for Ukraine's optimization problem is

$$\frac{\partial \pi_U}{\partial s} = x + (s - c_U) \cdot \frac{\partial x}{\partial s} = 0 \quad (6)$$

From (5) we know $\frac{\partial x}{\partial s} = -\frac{1}{2a}$ (7)

Substituting (7) into (6) we get the optimized transit fee:

$$\mathrm{s} = c_U + 2ax \quad (8)$$

The fact that (8) is increasing in x indicates that the transit fee set by Ukraine increases with higher transit volume.

Substituting (8) into (5), the profit-maximizing transit quantity of Russian gas is solved as:

$$x = \frac{b - c_R - c_U}{4a}$$

And Ukraine's optimal tariff is solved as

$$\mathrm{s} = \frac{b - c_R + c_U}{2}$$

So the profits for Russia and Ukraine when they do not cooperate are

$$\pi_U = \frac{(b - c_R - c_U)^2}{8a}$$

$$\pi_R = \frac{(b - c_R - c_U)^2}{16a}$$

Apparently the first mover advantage allows Ukraine to obtain two-thirds of total profit. Russia, on the other hand, achieves only the smaller part of total profit, regardless of the fact that it has the knowledge of what Ukraine has done in the previous stage. In other words, having more information is not always better in dynamic games.

In comparison with the benchmark, Ukraine achieves a positive profit because of its monopolistic position in transporting Russia gas.

3.1.2 cooperative game approach

In the situation of cooperative solution, Russia and Ukraine form a coalition and maximize their total profit by setting the optimized export quantity. They distribute the profit between themselves based on the Shapley value, as we assumed. Among the many possible contracts for allocating the overall profit between the partners, we assume that Ukraine will charge a two-part tariff for transiting Russian natural gas:

$\mathrm{T} = \mathrm{s} \cdot x + F,$

where T is the total transit tariff Ukraine receives from transporting Russian gas. F is the fixed fee which Ukraine appropriates from the total profit, and Ukraine only charges the constant marginal cost for transiting every unit of natural gas, implying

$\mathrm{s} = c_U$

The total profit from the cooperation is:

$$\pi_c = (p - c_R - c_U) \cdot x \tag{9}$$

The profits obtained by Russia and Ukraine are

$\pi_R = \pi_c - F$

$\pi_U = F$

As a coalition, the two countries will try to maximize their total profit by setting the optimized export volume. The optimization problem faced by the two countries is

$\max_x \pi_c = (p - c_R - c_U) \cdot x$

$\mathrm{s.t.} \quad \pi \geq \mathrm{F}, \mathrm{and}\ 0 \leq x \leq \bar{X}$

The Lagrange function is

$\mathrm{L} = (p - c_R - c_U) \cdot x + \lambda_1[(p - c_R - c_U) \cdot x - F] + \lambda_2(\bar{X} - x)$

The Kuhn-Tucker Conditions for this optimization problem are:

$\frac{\partial L}{\partial x} = [\frac{\partial p}{\partial x} \cdot x + (p - c_R - c_U)] \cdot (1 + \lambda_1) - \lambda_2 \leq 0$

$x \geq 0$

$x \cdot \frac{\partial L}{\partial x} = 0$

$\frac{\partial L}{\partial \lambda_1} = (p - c_R - c_U) \cdot x - F \geq 0$

$\lambda_1 \geq 0$

$\lambda_1 \cdot \frac{\partial L}{\partial {\lambda_1}_1} = 0$

$\frac{\partial L}{\partial \lambda_2} = \bar{X} - x \geq 0$

$\lambda_2 \geq 0$

$\lambda_2 \cdot \frac{\partial L}{\partial \lambda_2} = 0$

The same as in non-cooperative situation, we assume $x < \bar{X}$ and $x > 0$. Since Russia plays a dominant role in the natural gas supply chain of the East Europe region, Ukraine cannot appropriate the whole profit from cooperation, implying $\pi > F$, therefore we can get

$\lambda_1 = 0,\ \lambda_2 = 0,$

$$\frac{\partial L}{\partial x} = \frac{\partial p}{\partial x} \cdot x + (p - c_R - c_U) = 0 \quad \Longrightarrow \quad \frac{\partial p}{\partial x} \cdot x + p = c_R + c_U \tag{10}$$

The optimized export quantity of natural gas is

$$x = \frac{b - c_R - c_U}{2a}$$

And the total profit is

$$\pi_c = \frac{(b - c_R - c_U)^2}{4a}$$

Just as in the non-cooperative situation, the optimal export quantity only depends on both players' cost structure and the exogenously given parameters of the demand function.

Now let us consider how the total profit is distributed between the two partners. Because the pipeline in Ukraine is the only transport channels for Russia gas, Russia cannot export its product without Ukraine, which means the value created by Russia itself $v(R) = 0$ in (1) and (2). So the total pie is equally allocated between the two collaborators:

$$\varphi_R = \varphi_U = \frac{1}{2} v(RU) = \frac{1}{2} \pi_C$$

Which indicates that

$$F = \frac{1}{2} \pi_C$$

$$\pi_R = \pi_U = \frac{(b - c_R - c_U)^2}{8a}$$

Ukraine gains half of the profit from Russian gas because it owns the unique transit network. However the situation changes when Russia obtains a bypass, which will be analyzed in scenario two in the next part.

In comparison with the outcome when the market is perfectly competitive, total profit from the Russian gas supply chain when the two countries cooperate is the same with that in a competitive market. Difference lies in that Ukraine receives part of the total profit when it has monopolistic power.

3.1.3 summing up

Compared with the non-cooperative situation, the total profit from cooperation is larger than the sum of both countries' non-cooperative profits. Although Ukraine is indifferent between the two situations, Russia obtains twice the amount of profit under cooperation. Besides, the optimized export volume of Russian natural gas is larger when the two countries cooperate, implying a lower import price for European consumers.

In fact, the cooperation between the two countries can solve the double marginalization problem which exists in the independent situation. The aggregate profits in non-cooperative game approach is

$$\begin{aligned}&\pi_R(x) + \pi_U(s)\\&= (p - c_R - s) \cdot x + (s - c_U) \cdot x\\&= (p - c_R - c_U) \cdot x \qquad (11)\end{aligned}$$

which is the same expression with total profit under cooperation (9). However, difference lies in that the optimal x and s are chosen within two separate problems when there is no cooperation, whereas x is directly derived from FOC to maximize the same expression under cooperation. Hence the aggregate profits received in independent situation cannot exceed the maximum profits for the cooperative solution. Apparently the two countries gain more by coalition. The consumers in Europe also benefit from the suppliers' cooperation, because price decreases with a larger transit volume ($\frac{\partial p}{\partial x} = -a < 0$ in (3)).

Figure 1 illustrates the double marginalization problem. $p(x)$ is the inverse demand for Russia natural gas. $MR(x)$ is the marginal revenue curve corresponding to the demand curve. The demand for Ukraine's transmit network can be seen as a derived demand. As in (4), Russia chooses quantity by setting

$$MR(x) = c_R + s \qquad (12)$$

So we obtain the (inverse) derived demand for Ukraine's transmit network by rearranging (12):

$$s = MR(x) - c_R$$

In order to maximizes its own profit, Ukraine, the monopolistic transit country, will construct a marginal revenue curve shown in Table 1 as MR^s, and set this marginal revenue equal to its marginal cost c_U. The resulting transmission fee is shown as s_{nc} and the final price and volume of natural gas as p_{nc} and x_{nc}. The profits of Russia and Ukraine are given by π_R and π_U respectively.

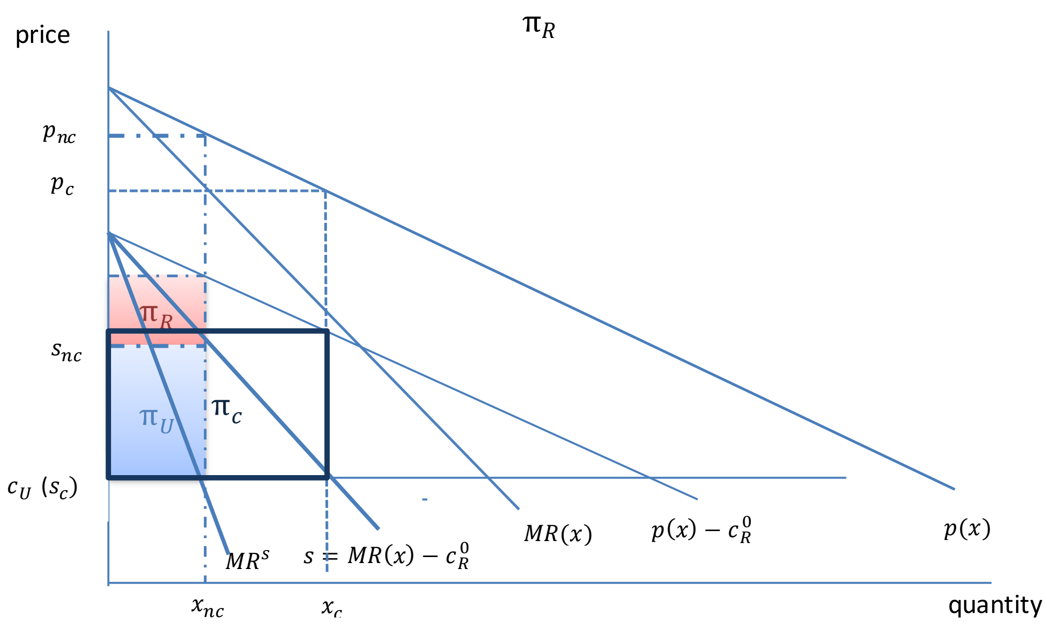
If Russia and Ukraine cooperates and maximizes their total profit, as in (10) they could find the optimized export quantity by setting

$MR(x) = c_R + c_U$

Or equivalently $MR(x) - c_R = c_U$

The corresponding volume and price are labeled x_c and p_c, and total profit is π_c, which is clearly larger than the sum of non-cooperative profits.

Figure 1. Double Marginalization



3.2 Scenario two: investment in bypass

In this scenario we assume Russia has decided to construct the *Nord Stream,* an offshore network directly connect Russia with its consumers in Europe. Now Russia has two options to transfer its natural gas, so Russia will set the transit quantity through Ukraine and through Nord Stream, denoted by x_U and x_N respectively. The per-unit cost for transit gas through *Nord Stream* is c_N , which is much higher due to the geography and long distance. Hence we make the assumption $c_N \geq c_U + c_R$, indicating that to transit gas through *Nord Stream* is more expensive than using the Ukraine pipeline. Technical requirements of *Nord Stream* are much higher due to the geography and long distance; not only that, both capacity cost and operating cost of *Nord Stream* are so large that the offshore network can be two to four times more expensive than other choices (Hubert and Ikonnikova, 2011). However the necessity of investing in other (probably expensive) networks lie in the fact that the capacities of the Ukraine pipelines cannot meet the transportation demand. In 1999 when Ukraine monopolized the Russian gas transportation, the utilization rate of its pipelines was near 100% (Hirschhausen et al. 2005). Therefore, despite of the large marginal cost of *Nord Stream*, Russia makes profit from the new investment as a result of the expanded capacity and the saved transit tariff which it pays to Ukraine .

Since it always takes time for the planning and construction of a pipeline, there is a time lag between the decision for new investment and the availability of the new capacity. Suppose a decision is made in $t = 0$ to invest in a new pipeline, planning, preparations and construction cause a delay of δ periods before investment can be realized and new capacity becomes available in $t = \delta + 1$. Before the new pipeline can be put into use during the first δ periods, Russia still has to transit natural gas through Ukraine at the cost of c_R . Once the new pipeline is available from period $t = \delta + 1$, Russia can set the transit quantity through both Ukraine and Nord Stream. For simplicity, we assume one country or the coalition receives the same annual profit from the existing capacity. Denote one country's or the coalition's profit before and after the new capacity as π^0 and π^1 respectively, then for a given discount rate r the present value of total profit one can receive is:

$$\frac{\bar{\pi}}{r} = \sum_{t=1}^{\delta} \frac{\pi^0}{(1+r)^t} + \frac{\pi^1}{r \cdot (1+r)^\delta}$$

Rearranging, we obtain the annuity $\bar{\pi}$ as a weighted average:

$$\bar{\pi} = (1-\alpha)\pi^0 + \alpha\pi^1; \quad \alpha = \frac{1}{(1+\mathrm{r})^\delta}.$$

For a given delay, the more forward looking and patient the players are, the smaller will be r, and the more weight will be put on the new investment.

For simplicity, we assume in the following analysis that the new investment can be achieved immediately, hence $\delta = 0, \alpha = 1$.

3.2.1 non-cooperative game approach

In the non-cooperative situation, Russia and Ukraine maximize their own profit independently. In the first stage, Ukraine will set the optimal transit tariff s to maximize its own profit

$$max_s\, \pi_U = (s - c_U) \cdot x_U \tag{13}$$

Then Russia will make its decision for export quantity in the second stage. Considering that the *Nord Stream* is a direct channel connecting Russia and its customers in Europe, Russia will prefer to transport gas through the *Nord Stream*, subject to the prevailing capacity constraint. Ukraine then gets to transport only the residual quantity, which can be calculated from Russia's profit-maximization problem:

$$max_{x_U}\, \pi_R = (p - c_R - s) \cdot x_U + (p - c_N) \cdot x_N$$

$$s.t.\, 0 \le x_U + x_N \le \bar{X}$$

Where $p = -a(x_U + x_N) + b$

Just the same as in the first scenario, we have loose constraint, indicating that $0 < x_U < \bar{X} - x_N$

The optimal transit volume via Ukraine is

$$x_U = \frac{b - c_R - s}{2a} - x_N \tag{14}$$

From Ukraine's optimization problem (13) we have

$$s = 2ax_U + c_U \tag{15}$$

Substituting (15) into (14), the profit-maximizing transit quantity of Russian gas is calculated as:

$$x_U = \frac{b - c_R - c_U}{4a} - \frac{x_N}{2}$$

And Ukraine's optimal transit fee is:

$$s = \frac{b - c_R + c_U}{2} - ax_N$$

In comparison with the non-cooperative situation in scenario one when there is no new investment, the transit quantity through Ukraine is now decreasing with x_N, and the transit tariff decreases with a smaller x_U, therefore Ukraine receives a lower profit after the new pipeline is constructed.

3.2.2 cooperative game approach

If Russia invests in the new pipeline when it cooperates with Ukraine, the coalition will set the optimal transit quantity through Ukraine to maximize the total profit. In terms of profit allocation, still we assume that Ukraine will charge a two-part tariff for transiting Russian natural gas:

$\mathrm{T} = \mathrm{s} \cdot x_U + F$

Where F is the fixed fee which Ukraine appropriates from the total profit, and Ukraine only charges the constant marginal cost for transiting every unit of natural gas, implying

$\mathrm{s} = c_U$

The optimization problem for the coalition is

$$max_{x_U} \pi_c = (p - c_R - c_U) \cdot x_U + (p - c_N) \cdot x_N \tag{16}$$

$s.t. \pi_c \geq F, 0 \leq x_U + \ x_N \leq \bar{X}$

Where $p = -a(x_U + \ x_N) + b$

Still we have loose constraints implying that $0 < x < \bar{X}$ and $\pi > \mathrm{F}$. The optimized transit quantity through Ukraine is:

$x_U = \frac{b - c_R - c_U}{2a} - x_N$

The transit volume through Ukraine is decreasing with that via *Nord Stream*. Besides, the transit quantity through Ukraine when it cooperates with Russia exceeds that when they act independently. As a result, Russia's total export quantity through both Ukraine and the *Nord Stream* is larger under the cooperative game solution. Therefore we can get the same conclusion as in scenario one that both the two countries and European consumers benefit from the cooperation between Russia and Ukraine.

In terms of profit allocation, since Russia can manage to reach consumers directly, the value created by Russia itself is no longer zero compared with the non-investment situation. If Ukraine does not cooperate with Russia, Russia transits all its gas through *Nord Stream* and receives a profit:

$v(R) = \pi(R) = (p - c_N) \cdot x$

Where $p = -ax + b$.

Russia will set the transit volume to maximize its profit, which leads to the result:

$x = \frac{b - c_N}{2a}$

The profits Russia and Ukraine obtain are:

$\varphi_R = v(R) + \frac{1}{2}\big(v(RU) - v(R)\big) = \frac{1}{2}(\pi_c + \pi(R))$

$\varphi_U = \frac{1}{2}\big(v(RU) - v(R)\big) = \frac{1}{2}(\pi_c - \pi(R))$

And φ_U is exactly the fixed transfer that Ukraine receives, implying:

$F = \frac{1}{2}(\pi_c - \pi(R))$

The total profit is not equally distributed between the two payers any more. Russia receives a larger fraction because of its bypass to reach consumers directly; whereas Ukraine gets a smaller part due to the loss of its monopoly transit role. The diversification of transit route increases Russia's bargaining power in the profit-sharing negotiation process.

4. Simulation and results

We perform a simulation of both scenarios in order to compare the effect of non-cooperative and cooperative game solution on export volume, price and profit allocation. In terms of the parameters in the import demand function, we use estimates by Hirschhausen et al. (2005) who obtains the results by running annual time-series data. The estimated parameters are $a = 0.789 \frac{US\$}{tcm \cdot 10^9\, cm}$, and $b = 141.1 \frac{US\$}{tcm}$. The marginal transit costs of Russia and Ukraine are set up to be $12.3 \frac{US\$}{tcm}$ and $5.14 \frac{US\$}{tcm}$, both data also originated from Hirschhausen et al.'s work.

With regards to the per-unit transformation cost in the *Nord Stream*, higher maintenance cost is required due to large offshore section and also higher energy cost due to higher pressure. In fact the off-shore transit route is high-tech-required and its operating cost is twice more expensive than that in Ukraine (Hubert and Ikonnikova, 2011). Therefore we estimate the marginal cost of the *Nord Stream* as Russia's transit cost to its western borders adding twice Ukraine's marginal operating cost, which turns out to be $22.58\frac{US\$}{tcm}$.

Ukraine's transit capacity is approximately 130 bcm per year. The utilization of its three pipelines (Central, Progress and Soyua) has long been 100% since 1999. The first line of Nord Stream was launched in November 2011 with a capacity of 27.5 bcm per year. The completion of its second train, scheduled in October 2012, will double the number and reach the designed capacity of 55 bcm per year.

Table 1 provides the results of our simulation based on the models developed in the previous section. Column (1) shows the results for the non-cooperative game approach when Ukraine acts as the monopolistic transit country. The export quantity from Russia's profit maximization is 39 bcm, and Ukraine's profit-maximizing transit cost is 67 US$ per tcm. Because of its first-mover advantage, Ukraine acquires two thirds of the total profit from the Russian gas export activity, which is 2423 $\mathrm{mnUS\$}$. And Russia's profit is only half that volume due to its reliance on Ukraine's transit route.

In contrast, column (4) shows the results for cooperation between the two bilateral monopolists. Note the profit-maximizing export quantity has doubled the number in independent situation. This difference originates from the elimination of Ukraine's transit mark-up, leading to a lower price and an increased demand.

Although Ukraine's situation is not improved, Russia now acquires twice the profit from independence. The joint profit $\pi_R + \pi_u$ is 4845 mn US$, as compared to joint profit of 3634 mn US$ in the non-cooperative scenario. Since Russia has no transit channel besides Ukraine, the joint profit is exactly the additional earnings brought by

Ukraine to the coalition. The additional profit is equally shared between the two countries based on Shapley Value.

A comparison between column (1) and column (4) also shows an increase in consumer surplus for West European gas importers as a result of Russia and Ukraine's cooperation. While the price for imported gas at the European border amounted to 110 $\frac{\mathrm{US\$}}{\mathrm{tcm}}$ in the transit monopoly constellation, it falls to 79 $\frac{\mathrm{US\$}}{\mathrm{tcm}}$ in the cooperative game solution. On the other hand, Russian gas will become more competitive in West Europe and therefore is expected to gain more market share in Europe.

We now turn to the comparison of solutions in the new investment situation, i.e. by taking into account the *Nord Stream* as an alternative route. Column (2) and (5) illustrate the results of non-cooperative and cooperative game approach when the new capacity is 27.5 bcm. While the outcomes of the completed capacity, which is 55 bcm, are shown in column (3) and (6). Ukraine's transit quantity decreases as the new capacity in *Nord Stream* increases. A comparison between column (2) and (3) shows that in the non-cooperative situation, Russia gains more profit from the expanded capacity, while Ukraine loses revenue as a result of decreased transit quantity. Consumers also benefit from the expanded volume and decreased price. However, the results in column (5) and (6) indicate that not only Ukraine but also Russia loses profit from the increasing of the new investment when cooperation exists. The reason is that in the cooperative situation, Russia spends much more in transporting gas through *Nord Stream* since Ukraine only charges a transit fee equal to its marginal cost in their contract. Nevertheless, the increasing new capacity makes Ukraine's contribution to their coalition smaller ($\mathrm{v(RU)} - \mathrm{v(R)}$ is smaller), leading to a more advantageous place for Russia in profit allocation.

Comparing the outcomes in non-cooperative situation with that from cooperation, it can be inferred that cooperation always leads to a higher export volume and a lower price, a logical result of the eliminated double marginalization. However, compared with the situation when Ukraine is the unique transit route, Ukraine now clearly loses transit volumes and profits due to the loss of its monopolistic transit place. The weaker position of Ukraine also leads to a lower mark-up on the transit fee, which falls from 67 $\frac{\mathrm{US\$}}{\mathrm{tcm}}$ to 24 $\frac{\mathrm{US\$}}{\mathrm{tcm}}$. Especially when the two countries cooperate, Russia's acquirement of a direct bypass strongly improves its bargaining strength, leaving a very small additional profit allocated to Ukraine.

A comparison between column (4) and column (5) (6) shows that Russia's export quantity remains the same as in the monopolistic cooperation scenario (78 bcm); as long as the capacity of the direct bypass is limited, the export quantity is determined by the marginal cost of Ukraine. In consequence, the import price for European consumers also stays the same. The consumer surplus is 2423 mnUS$ in the three columns. However, although Russia's allocated profit is much higher when it develops a new transit route, the total profit is smaller. That is to say, Russia seeks its own benefit at the cost of its partner. The benefit of Russia's investment in the outside option lies only in the increase of its bargaining power in the ex post profit-allocation process. The decreasing total welfare in column (5) and (6) indicates that from the point view of social surplus, Russia's seek for bargaining externalities leads to inefficient overinvestment.

The origination of the overinvestment problem can be explained as followed. In the non-cooperative situation when there is new investment, the joint profit of the two countries is

$$\pi_U + \pi_R = (s - c_U) \cdot x_U + [(p - c_R - s) \cdot x_U + (p - c_N) \cdot x_N] \tag{17}$$

Rearranging (17), we get

$$\begin{aligned}\pi_U + \pi_R = {} & (s - c_U) \cdot x + (p - c_R - s) \cdot x \\ & +[(p - c_N) \cdot x_N - (s - c_U) \cdot x_N - (p - c_R - s) \cdot x_N]\end{aligned} \tag{18}$$

In which the first two items are exactly the expression for joint profit in non-cooperative situation without new investment. Whereas the three items in the brackets explains the profit increase after *Nord Stream* is built: the profit from transporting gas through the *Nord Stream* resulting from an expanded capacity; the loss of profit for Ukraine due to *Nord Stream*; and the loss of profit for Russia because of transporting gas through *Nord Stream* instead of Ukraine. As is mentioned in previous section, the existence of double marginalization in non-cooperative situation leads to the un-maximized transit outcome through Ukraine, which makes the value in the bracket positive.

In terms of the situation of cooperation, we can rearrange the total profit under new investment (16) as:

$$\pi_c = (p - c_R - c_U) \cdot x + [(p - c_N) \cdot x_N - (p - c_R - c_U) \cdot x_N]$$

Apart from the first item which is the same as total profit in monopoly situation, the items in the bracket include profit from new capacity and the loss of profit from *Nord Stream*. Different from (18), the loss of profit here exceeds the earnings from new capacity. The reason is that cooperation eliminates the transit mark-up, thus maximizing the export profit through Ukraine. Therefore the transit volume through the expensive Nord Stream could be more profitable should it be transported via Ukraine. The items in the bracket turn out to be negative, which leads the total cooperation profit with new expensive transit route is smaller than that in monopolistic transit situation.

Table1. Simulation results

		Non-cooperative game approach			Cooperative game approach		
		Ukraine transit monopoly	New investment in *Nord Stream*		Ukraine transit monopoly	New investment in *Nord Stream*	
		(1)	(2)	(3)	(4)	(5)	(6)
Exogenous:	x_N(bcm)	-	27.5	55	-	27.5	55
Endogenous:	x(bcm)	39.18	52.93	66.68	78.37	78.37	78.37
	x_U(bcm)	39.18	25.43	11.68	78.37	50.87	23.37
	$p(\frac{US\$}{tcm})$	110.19	99.34	88.49	79.27	79.27	79.27
	$s(\frac{US\$}{tcm})$	66.97	45.27	23.58	5.14	5.14	5.14
	π_R or φ_R (mnUS$)	1211.33	3172.95	4239.56	2422.65	4577.42	4506.75
	π_U or φ_U (mnUS$)	2422.65	1020.67	215.37	2422.65	126.54	55.86
	$\pi_R + \pi_U$ or π_c(mnUS$)	3633.98	4193.62	4454.93	4845.31	4703.96	4562.61
	v(R)(mnUS$)	-	-	-	0	4450.88	4450.88
	v(RU) − v(R)(mnUS$)	-	-	-	4845.31	253.07	111.72
	CS (mnUS$)	605.66	1105.33	1754.17	2422.65	2422.65	2422.65
	Overall welfare (mnUS$)	4239.64	5298.95	6209.10	7267.96	7126.61	6985.26

5. Conclusion

In this paper we analyze the strategic behavior of the countries in the Russia gas supply chain for transporting Russian gas to Western Europe, with a focus on the relation between Russia and Ukraine. Both non-cooperative game theory and cooperative game theory are used. The two countries can act independently or to form a coalition. Besides, Russia can make new investment in bypass.

Our analysis shows that cooperation is always the first-best choice for Russia, since it removes Ukraine's transit mark-up and leads to an increased export volume. Price goes down due to the elimination of double marginalization, thus benefiting consumers in European countries.

Investment in bypass can improve Russia's situation. If the two countries do not cooperate, the expanded capacity allows Russia to transfer a larger volume of gas without extra transit tariff. In circumstance of cooperation, Russia obtains a much stronger bargaining advantage over profit allocation due to the outside option. Yet developing new expensive route can be socially inefficient under cooperation, with the only beneficiary being Russia.

The policy indication drawn from our analysis is that, from the view point of social welfare, Russia's cooperation with Ukraine should be encouraged and Russia's overinvestment in expensive new capacities should be avoided.

Three major limitations in this paper merit further investigation. First, Russia's eager for more profit allocation may lead to overinvestment in capacity, and how to alleviate or eliminate this inefficiency remains to be solved. Besides, we only consider Ukraine as the monopolistic transit country, in fact, the existence of other possible transit routes like *Yamal* (through Belarus) and *Baltic* (through Poland) might change the outcome once joint in the model. Last but not least, a more precise estimation of the European demand function for gas using more recent data can probably increase the quality of the simulation results further.

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