How to sell Russian gas to Europe via Ukraine?

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Abstract

In recent years, the problems of Russian gas supplies to Europe got quite serious as the events of January 2009 have shown. From an economic point of view, the sources of these problems are the monopoly of Ukraine as a transit country, on one hand, and Russian monopoly on supplies of gas to Ukraine, on the other. The paper analyses different schemes of supplying Russian gas to Europe and Ukraine. It is shown that under existing agreements on supplies of Russian gas to Europe, Ukraine does not take proper advantage of its position as a monopoly transit country. On its part, Russia could benefit by setting the price of gas supplied to Ukraine as a function of transit tariff set by Ukraine.

1. Introduction

Russia is a major natural gas exporter to Europe, accounting for 25 per cent of European gas consumption and 60 per cent of its imports. All Russian gas for Europe is exported by one state-controlled company, Gazprom, which makes it possible for Russia to exercise its market power on the European gas market. Currently, Russian gas is supplied to Europe under long-term contracts, some of which will expire in decades. Under these contracts, the price of natural gas is determined by the price of a basket of petroleum products, thus not directly dependent on gas demand.

While Russia is a dominant player on the European gas market, its profits are significantly threatened by its dependence on gas transit countries such as Ukraine and Belarus. Even with North Stream gas pipeline in action, Russia will still be dependent on transit countries. The existing pattern of Russian gas supplies to Europe dates back to the Soviet time, when main gas export pipelines were constructed. Under this pattern, Russia delivers natural gas to Western and Central Europe via transit countries having no control over

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natural gas transportation. Technically, the same gas pipeline is used both for Russian gas exports to Europe and Ukraine that makes it impossible to cut off gas supplies to Ukraine while continuing supplying gas to Europe.

While some transit countries (Slovakia, Poland) stick to the rules set by the Energy Charter, Ukraine and Belarus try to take advantage of their geographical position to gain extra profits.

Nearly all Russian gas is transported to Europe via Ukraine and Belarus, which accounts for 80 per cent and 20 per cent of exports, respectively. Thus, Ukraine is actually a monopolist on the market of gas transportation to Europe, and at the same time, has to import 60 per cent of its gas demand.[1] Given that Turkmen gas, consumed by Ukraine, is delivered through the Russian territory, Russia is, in fact, a monopolistic gas exporter for Ukraine. This factor has dominated the Russian–Ukrainian 'gas' relations ever since early 1990 after the collapse of the Soviet Union. Actually, explicitly or implicitly, Ukraine tried to use its dominant position on the route of Russian gas exports to Europe to get Russian gas at a discount.

Economic and political issues of Russian–Ukrainian and Russian–Belorussian 'gas' relationships are discussed in a number of papers. Stern (2006) and Yafimava and Stern (2007) analysed the negotiation process between Russia and Ukraine and Russia and Belarus on the price of natural gas supplied to Ukraine and Belarus and on the tariffs of Russian gas transportation to Europe. Opitz and von Hirschhausen (2000), Chollet *et al*. (2000) and Meinhart *et al*. (2005) considered issues relating to Russian gas transportation to Europe under the monopoly and duopoly of transit countries. Tarr and Thomson (2003) evaluated the effectiveness of Russia's price discrimination policy for Russian and European consumers. Hubert and Ikonnikova (2003, 2004, 2005) analysed the effects of coalitions among Russia, Ukraine, Poland and Slovakia as well as that of the construction of the North European gas pipeline on Russia's market power. Grais and Zheng (1996) considered a relationship between a gas supplier (Russia), transit countries (Belarus, Ukraine, Slovakia and the Czech Republic) and Russian gas importers in the Stackelberg model where the supplier is a leading player. Yegorov and Wirl (2009) analysed strategic interaction of the three players [Russia, Ukraine and the European Union (EU)], within the bargaining model, relative to the 'gas' crisis of January 2009.

All the aforementioned papers, however, do not take into account that transit countries are strongly dependent on supplies of Russian gas. In contrast, the present paper analyses a number of trading schemes when a transit country depends on supplies of Russian gas. The study employs the partial equilibrium model. For simplicity, it is assumed that Ukraine is the only transit country for Russian gas. Although there are several locations where Russia sells its gas to Europe, it is assumed that all Russian gas exported to Europe is sold at Ukraine's Western border. The following sections present the models of some schemes of Russian gas trade with Europe and Ukraine.

2. Russian gas is supplied to Europe at Ukraine's western border under long-term contracts

As mentioned earlier, under the existing scheme of Russian gas supplies to Europe the contract price of gas for European consumers is determined by the price of a basket of petroleum products and does not directly depend on gas demand. Thus, gas price and, accordingly, gas supplies to Europe are given exogenously.

On the whole, the practice of the Russia–Ukraine relationships shows that there is explicit or implicit dependence between the price of the Russian gas supplied to Ukraine and transportation tariff. In line with this observation, the following model of the Russian–Ukrainian 'gas' relations is considered.

According to existing contracts, Russia supplies to Europe a volume of natural gas Q_E at a price P_E, with Q_E and P_E given exogenously. For simplicity, it is assumed that natural gas losses while its transportation via Ukraine can be ignored. For transporting Russian gas to Europe via Ukraine, the latter charges a tariff equal to τ, while Ukraine's gas transportation costs equal $C_{UT}(Q_E)$. Ukraine is a major consumer of Russian gas, Ukraine's demand for natural gas function is $Q_U(P_U)$. Ukraine produces the volume $q_U = const$ of gas, the rest—$Q_U - q_U$—is imported by Ukraine from Russia. Since $q_U << Q_U$, it can be assumed that Russia is a dominant player on the Ukrainian gas market. Russia's costs of gas production and transportation to Ukraine's border are $C_R(Q_E + Q_U)$. Ukraine's gas production costs are $C_{UE}(q_u)$. If the price of the Russian gas supplied to Ukraine is set independently from the transportation tariff, then, with exogenously given P_E и Q_E, Ukraine, taking advantage of its monopoly position as a transit country, will set a tariff that will allow it to appropriate all the gas rent. On its part, Russia, taking advantage of being a sole gas exporter to Ukraine, will set a monopoly price for gas supplied to Ukraine. Taking into account the difference in the volume of trade with Europe and Ukraine, it is clear that this option is unprofitable for Russia. Therefore, in what follows, we consider a trading where Russia sets the price of gas supplied to Ukraine, which depends on the transportation tariff, i.e. the function $P_U(\tau)$, $P_U' > 0$. It is assumed that Ukraine aims at maximising its social welfare, W_U, determined as a sum of Ukrainian consumer's surplus $CS(P_U)$, profits from gas transportation to Europe and profit of Ukrainian gas-producing companies:

$$W_U = CS(P_U) + \tau \cdot Q_E - C_{UT}(Q_E) + P_U \cdot q_U - C_{UE}(q_U) \quad (1)$$

Then, given the function $P_U(\tau)$, Ukraine solves the following maximisation problem:

$$W_U(\tau_*) = \max_{\tau} \left[\int_{P_U(\tau)}^{\infty} Q_U(\xi)\, d\xi + \tau \cdot Q_E - C_{UT}(Q_E) + P_U \cdot q_U - C_{UE}(q_U) \right] \quad (2)$$

The first-order condition (FOC) for equation (2) is as follows:

$$Q_E - [Q_U(P_U(\tau)) - q_U] \cdot P_U'(\tau) = 0 \tag{3}$$

The corresponding second-order condition (SOC) is

$$Q_U'(P_U) \cdot [P_U'(\tau)]^2 + [Q_U(P_U) - q_U] \cdot P_U''(\tau) \geq 0 \tag{4}$$

from which it follows that $P_U''(\tau) > 0$.

Solving the maximisation equation (2), under the given by Russia function $P_U(\tau)$, Ukraine determines an optimal value of the tariff for Russian gas transportation to Europe τ_*. In its turn, Russia, knowing the optimal for Ukraine gas transportation tariff τ_*, can maximise its profit $\pi_R(P_U(\tau_*))$ from gas supplies to Europe and Ukraine by choosing the optimal function $P_U(\tau)$:

$$\begin{aligned} \pi_R(P_U^*(\tau_*)) = \max_{P_U(\tau_*)} \{ & P_E \cdot Q_E + P_U(\tau_*) \cdot [Q_U(P_U^*(\tau_*)) - q_U] \\ & - C_R(Q_E + Q_U(P_U^*(\tau_*)) - q_U) - \tau_* \cdot Q_E \}. \end{aligned} \tag{5}$$

It should be noted that the preceding approach is valid provided Russia has significantly high negotiating power in dealing with Ukraine, i.e. Russia can set the function $P_U(\tau)$, which is accepted by Ukraine. In the opposite case, Ukraine can set the function $\tau(P_U)$, which is accepted by Russia. Obviously, the first case, which seems to be more realistic, is preferable for Russia, and it is analysed subsequently.

Solving the optimisation equations (2) and (5) in the general form is not an easy task. One can, however, suggest an algorithm for the solution of the aforementioned problem by specifying the function $P_U(\tau)$. A function $P_U(\tau, \vec{a})$ is specified, where $\vec{a}$ is a vector of the parameters that ensure that equation (4) is satisfied. From equation (3), the function $\tau_*(\vec{a})$ is determined. Substituting $\tau_*(\vec{a})$ into equation (5) yields the following optimisation problem:

$$\begin{aligned} \pi_R(P_U(\tau_*, \vec{a}_*)) = \max_{\vec{a}} \{ & P_E \cdot Q_E + P_U(\tau_*(\vec{a}), \vec{a}) \cdot [Q_U(P_U(\tau_*(\vec{a}), \vec{a})) - q_U] \\ & - C_R(Q_E + Q_U(P_U(\tau_*(\vec{a}), \vec{a})) - q_U) - \tau_*(\vec{a}) \cdot Q_E \}. \end{aligned} \tag{6}$$

Let Ukraine's demand function for natural gas be linear,

$$Q_U = a_U - b_U \cdot P_U. \tag{7}$$

It is also assumed that marginal costs of Russian gas production and transportation to Ukraine's border, of gas transportation via Ukraine and of gas production in Ukraine are constant and equal, respectively:

$$C_R' = c_R = const, C_{UT}' = c_{UT} = const, C_{UE}' = c_{UE} = const. \tag{8}$$

Taking into account that the linear function $P_U(\tau, \vec{a})$ does not satisfy equation (4), for simplicity, it is sought in the following form:

$$P_U = \alpha \cdot \tau^2, \alpha = const.$$

From equations (3) and (4), it follows that $\alpha > 0$. Then, equation (3) will be as follows:

$$[a_U - q_U - b_U \cdot \alpha \cdot \tau^2] \cdot 2\alpha \cdot \tau = Q_E.$$

from where $\tau_*(a)$ is obtained,

$$\tau_* = -2 \cdot \sqrt{\frac{a_U - q_U}{3 \cdot b_U \cdot \alpha}} \cdot \cos\left\{\frac{1}{3} \cdot \left[\arccos\left(\frac{3\sqrt{3}}{4} \cdot \frac{Q_E \cdot \sqrt{b_U}}{\sqrt{\alpha \cdot (a_U - q_U)^3}}\right) - 2 \cdot \pi\right]\right\}.$$

Substituting $\tau_*(\alpha)$ into equation (6) and solving the optimisation problem, we obtain optimal for Russia values of α.

However, under certain assumptions and a particular specification of the functions Q_U (P_U), $P_U(\tau)$, one can obtain the solution of the problem in the analytical form. Next, such a case is considered. It is assumed that all the gas consumed by Ukraine is imported from Russia. Then,

$$W_U = CS(P_U) + \tau \cdot Q_E - C_{UT}(Q_E). \tag{9}$$

Accordingly, equation (3) will be as a follows:

$$Q_E - Q_{UR}(P_U(\tau)) \cdot P_U'(\tau) = 0, \tag{3'}$$

where $Q_{UR}(P_U(\tau))$ is the Ukraine's demand function for the Russian gas.

Consider next the problem of finding the optimal function $P_U(\tau)$ under its exogenously given specification. It is assumed that the function $Q_{UR}(P_U)$ is characterised by a constant price elasticity of demand:

$$\bar{Q}_{UR} = \bar{P}_U^{-\eta}, \bar{Q}_{UR} = \frac{Q_{UR}}{Q_{UR0}}, \bar{P}_U = \frac{P_U}{P_{U0}}, \tag{10}$$

where Q_{UR0} and P_{U0} are the actual values of Russian gas consumed by Ukraine and of its price within a certain period.

In the subsequent discussion, we assume that $\eta < 1$, which corresponds to the overwhelming number of estimates of the short-term price elasticity of natural gas demand in industrially developed countries (see e.g. Liu, 1983; Al-Sahlawi, 1989).

The sought-for dependence of the price of the Russian gas supplied to Ukraine on the transportation tariff is assumed to be as follows:

$$\bar{P}_U = \alpha \cdot \bar{\tau}^{\beta}, \bar{\tau} = \frac{\tau}{P_{U0}}, \alpha, \beta = const, \alpha > 0, \beta > 0. \tag{11}$$

Then the problem is to find the constant coefficients α,β, which ensure the maximum profit Russia gets from sales of gas to Europe and Ukraine.

Russia offers to Ukraine the price of gas, which depends on the transportation tariff, i.e. equation (11). Based on this equation, Ukraine chooses an optimal value of the transportation tariff {from the maximisation of its social welfare [equation (9)]}.

Then after substituting equations (10) and (11) into equation (3′), we obtain

$$\bar{Q}_E - \alpha^{1-\eta}\cdot\beta\cdot\bar{\tau}^{(1-\eta)\cdot\beta-1} = 0, \quad \bar{Q}_E = Q_E/Q_{UR0},$$

from which we find an optimal value of the transportation tariff set by Ukraine:

$$\tau_* = \left(\frac{\bar{Q}_E}{\alpha^{1-\eta}\cdot\beta}\right)^{\frac{1}{(1-\eta)\cdot\beta-1}}. \quad (12)$$

In the case under consideration, equation (4) will be as follows:

$$\bar{Q}_{UR}\cdot\alpha^{1-\eta}\cdot\beta\cdot\bar{\tau}^{(1-\eta)\beta-2}\cdot(\beta-1-\eta\cdot\beta)\geq 0,$$

which yields a restriction on the values of the coefficient β

$$\beta \geq \frac{1}{1-\eta}. \quad (13)$$

Then Russia's profit from gas sales to Europe and Ukraine will be as follows:

$$\bar{\pi}_R = \frac{\pi_R}{P_{U0}\cdot Q_{UR0}} = (\bar{P}_E - \bar{c}_R)\cdot\bar{Q}_E + \alpha^{1-\eta}\cdot\bar{\tau}^{(1-\eta)\beta} - \bar{c}_R\cdot\alpha^{-\eta}\cdot\bar{\tau}^{-\eta\cdot\beta} - \bar{Q}_E\cdot\bar{\tau}, \quad (14)$$

where $\bar{c}_R = c_R/P_{U0}$.

Substitution of the value of the optimal transportation tariff equation (12) into equation (14) yields

$$\begin{aligned}\bar{\pi}_R = (\bar{P}_E - c_R)\cdot\bar{Q}_E + \bar{Q}_E^{-\frac{(1-\eta)\beta}{(1-\eta)\beta-1}}\cdot\alpha^{-\frac{1-\eta}{(1-\eta)\beta-1}}\cdot\beta^{-\frac{1}{(1-\eta)\beta-1}}\cdot(\beta^{-1}-1)\\ -\bar{c}_R\cdot\bar{Q}_E^{-\frac{\eta\cdot\beta}{(1-\eta)\beta-1}}\cdot\alpha\bar{Q}_E^{-\frac{\eta}{(1-\eta)\beta-1}}\cdot\beta - \bar{Q}_E\cdot\bar{\tau}^{-\frac{\eta\cdot\beta}{(1-\eta)\beta-1}}.\end{aligned} \quad (15)$$

From equation (15), it is easy to see that there exists an optimal value $\alpha = \alpha_*$, which ensures maximum profit for Russia. Appropriate calculations result in the following expression for α_*:

$$\bar{\alpha}_* = \bar{Q}_E^{\beta}\cdot\left(\frac{1-\eta}{\eta}\cdot\frac{1}{\bar{c}_R}\right)^{(1-\eta)\cdot\beta-1}\cdot\left(1-\frac{1}{\beta}\right)^{(1-\eta)\cdot\beta-1}\cdot\beta^{-(1+\eta\beta)}. \quad (16)$$

Substituting equation (16) into equation (15) and carrying out necessary transformations, we obtain

$$\bar{\pi}_R = (\bar{P}_E - \bar{c}_R)\cdot\bar{Q}_E - \frac{\bar{c}_R^{1-\eta}}{\eta^{\eta}\cdot(1-\eta)^{1-\eta}}\cdot(\beta-1)^{\eta}.$$

It is easy to see that $\frac{\partial \bar{\pi}_R}{\partial \beta} < 0$, from where, taking into account equation (13), it follows

$$\beta_* = \frac{1}{1-\eta}. \tag{17}$$

Using equation (17), we obtain the following expressions for the sought values:

$$\begin{aligned} \alpha_* &= [(1-\eta)\cdot \bar{Q}_E]^{\frac{1}{1-\eta}}, \\ \bar{\tau}_* &= \frac{1}{\bar{Q}_E}\cdot\frac{\bar{c}_R^{1-\eta}}{1-\eta}, \\ \bar{P}_U^* &= \bar{c}_R, \end{aligned} \tag{18}$$

$$\bar{\pi}_R^* = (\bar{P}_E - \bar{c}_R)\cdot \bar{Q}_E - \frac{\bar{c}_R^{1-\eta}}{1-\eta}. \tag{19}$$

From equations (18) and (19), and taking into account that $\bar{c}_R < 1$, it follows that $\frac{\partial \bar{\tau}_*}{\partial \eta} > 0$, $\frac{\partial \bar{\pi}_R^*}{\partial \eta} < 0$, i.e. the higher the price elasticity of Ukraine's demand for Russian gas is, the higher the transportation tariff is and the lower Russia's total profit is, which is well in agreement with the economic theory.

It should be noted that eventually, the price of the Russian gas supplied to Ukraine is set at a level equal to its marginal production and transportation costs.

3. Russia sells gas to Europe at Ukraine's western border under a given demand for gas function

Earlier, we considered the case when the volume of Russian gas supplied for Europe and its price were determined by long-term contracts based on the price of a basket of petroleum products without explicitly taking into account European demand for gas (i.e. exogenously given). Let us consider further a case when the volume of gas supply to Europe and its price are determined by demand for gas on the European market. Apart from Russia, natural gas is supplied to the European market by European producers and other gas exporters. It is assumed that as a major gas supplier for Europe, Russia is a dominant player on the European market under competitive fringe. This assumption can be justified by the decision of the European Commission to liberalise the European gas market with respect to local producers. Residual demand function for the Russian gas on the European gas market is $Q_E\,(P_E)$. Further, it is assumed that all Russian gas is supplied to Europe via Ukraine, the latter consuming Russian gas according to the demand function $Q_U\,(P_U)$. Then, Russia's profit from gas supplies to Europe and Ukraine is determined as follows:

$$\pi_R = (P_E - c_R - \tau)\cdot Q_E(P_E) + (P_U - c_R)\cdot[Q_U(P_U) - q_U)]. \tag{20}$$

Next, we consider a case when Russia and Ukraine negotiate gas supplies to Ukraine independently of transportation tariff, i.e. when the price of Russian gas supplied to Ukraine does not depend on the transportation tariff set by Ukraine. In this case, determination of the transportation tariff and the price of the Russian gas supplied to Ukraine present two separate problems. Consider first the problem of determining the transportation tariff. As in the previous section, it is assumed that conditions (8) are satisfied. Then, from the condition of maximising Russia's profit from gas supplies to Europe with respect to its price under exogenously given transportation tariff, we get the following FOC:

$$Q_E + (P_E - c_R - \tau)\cdot Q_E' = 0, \tag{21}$$

from where we find an optimal price of Russian gas supplied to Europe dependent on the transportation tariff set by Ukraine, i.e. $P_E^*(\tau)$.

From equation (21), one can obtain

$$\frac{dP_E}{d\tau} = \frac{Q_E'}{2Q_E' + (P_E - c_R - \tau)\cdot Q_E''},$$

from which, among other things, it follows that for the linear demand function $\frac{dP_E}{d\tau} = \frac{1}{2}$.

Ukraine's profit from transportation of the Russian gas to Europe will be as follows:

$$\pi_U = (\tau - c_{UT})\cdot Q_E(P_E^*(\tau)).$$

It is assumed that Ukraine knows the function $P_E^*(\tau)$ and sets the transportation tariff by maximising its profit from transportation of the Russian gas to Europe, which yields

$$Q_E(P_E^*(\tau)) + (\tau - c_{UT})\cdot Q_E' \cdot P_E^{*\prime} = 0. \tag{22}$$

From equation (22), the optimal for Ukraine transportation tariff τ_* is obtained, and then from equation (21), we find the price of Russian gas supplied to Europe.

Consider next a case when the demand function for Russian gas in Europe (as in Ukraine) is linear:

$$Q_E = a_E - b_E \cdot P_E. \tag{23}$$

Then from equation (21), we obtain

$$P_E^* = \frac{1}{2}\left(\frac{a_E}{b_E} + c_R + \tau\right). \tag{24}$$

Substituting equation (24) into equation (22), yields

$$\tau_* = \frac{1}{2}\left(\frac{a_E}{b_E} - c_R + c_{UT}\right). \tag{25}$$

From equation (24) and equation (25), it follows

$$P_E^* = \frac{1}{4}\left(3\frac{a_E}{b_E} + c_R + c_{UT}\right).$$

Note that this scheme of gas trade with Europe (when Russia sells its gas to Europe on Ukraine's Western border, and the price of Russian gas supplied to Ukraine does not depend on transportation tariff) is beneficial for Ukraine, which, in this case, is (according to a Stackelberg model) a leading player. The price of Russian gas supplied to Ukraine is determined from maximisation of Russia's profit from gas supplies to Ukraine under Russian monopoly on Ukrainian residual demand market. Then, the optimal for Russia price and volume of gas supplied to Ukraine will be as follows:

$$P_U^* = \frac{a_U - q_U + b_U \cdot c_R}{2b_U}, \quad Q_U^* = \frac{1}{2}(a_U - q_U - b_U \cdot c_R). \tag{26}$$

Thus, Russia's total profit from gas supplies to Europe and Ukraine will be

$$\pi_R^* = \frac{1}{16b_E} \cdot [a_E - b_E \cdot (c_R + c_{UT})]^2 + \frac{1}{4b_U} \cdot (a_U - q_U - b_U \cdot c_R)^2. \tag{27}$$

Earlier, the case when the price of Russian gas, supplied to Ukraine, has been set independently of transportation tariff was considered. However, as has been shown earlier, such a policy could be inefficient for Russia. That is why we consider a case when Russia sets the price of gas, supplied to Ukraine, depending on a transportation tariff, set by Ukraine, i.e. $P_U = P_U(\tau)$. Then, maximisation of the Russian profit from gas supplies to Europe under the given transportation tariff yields, as in a previous case, FOC equation (21), from which the price of Russian gas, supplied to Europe, is defined as a function of the transportation tariff [equation (24)]. It is assumed that Ukraine chooses the value of transportation tariff from maximisation of its social welfare [equation (1)]. The corresponding FOC will be as follows:

$$-[Q_U(P_U(\tau)) - q_U] \cdot P_U'(\tau) + Q_E(P_E(\tau)) + (\tau - c_{UT}) \cdot Q_E' \cdot P_E' = 0. \tag{28}$$

From equation (28), the optimal (for Ukraine) value of transportation tariff is obtained. The SOC for the problem of maximisation of Ukraine's social welfare will be

$$-Q_U' \cdot P_U' - (Q_U - q_U) \cdot P_U''(\tau) + 2Q_E' \cdot P_E' + (\tau - c_{UT}) \cdot (Q_E'' \cdot P_E' + Q_E' \cdot P_E'') \le 0. \tag{29}$$

Again, as in a previous case, it is assumed that demand functions for the Russian gas in Europe and Ukraine are linear, equations (7) and (23). Then, dependence of the price of Russian gas supplied to Europe on transportation tariff is defined by equation (24). The function $P_U(\tau)$ is assumed, for simplicity, to be linear:

$$P_U(\tau) = \alpha \cdot \tau. \tag{30}$$

Then from equation (29), the following constraint on coefficient α can be derived:

$$\alpha \leq \sqrt{b_E / b_U}.$$

Substituting equation (30) into equation (27) and taking into account the specification of the demand functions, equations (7) and (23), as well as equation (24), we set the following expression for the optimal value of transportation tariff:

$$\tau_* = \frac{a_E - b_E \cdot (c_R - c_{UT}) - 2 \cdot (a_U - q_U) \cdot \alpha}{2(b_E - b_U \cdot \alpha^2)}. \tag{31}$$

Then, from the maximisation of the Russian profit in equation (20), the optimal values of coefficient α are obtained:

$$\max_{\alpha} \left\{ \frac{1}{4b_E} [a_E - b_E \cdot (c_R + \tau_*)]^2 + (\alpha \cdot \tau_* - c_R) \cdot [a_U - q_U - b_U \cdot \alpha \cdot \tau_*] \right\},$$

where τ_* is defined by equation (31).

4. All exported gas by Russia is sold to Ukraine

One of the options for Russia is to sell all the gas it supplies to Europe and Ukraine to Ukraine, while the latter decides how much of this gas and at what price it will resell to Europe and how much to consume. In this case, there are no problems of gas transportation to Europe for Russia, which could act in its relations with Ukraine, according to a Stackelberg model, as a leading player. Let the price of gas, Russia sells to Ukraine, be P_R, the rest notations remain as before. The price of gas for Ukrainian consumers is $P_U = P_R$. It is assumed that Ukraine knows European demand function for the Russian gas. Then, Ukraine's profit from selling Russian gas to Europe will be

$$\pi_U = (P_E - P_R - c_{UT}) \cdot Q_E(P_E).$$

Maximisation of Ukraine's profit from reselling Russian gas to Europe yields the following FOC:

$$(P_E - P_R - c_{UT}) \cdot Q'_E(P_E) + Q_E(P_E) = 0, \tag{32}$$

from which the function $P_E(P_R)$ is obtained.

Then, Russia's profit from selling gas to Ukraine (taking into account its consumption by Europe and Ukraine) will be

$$\pi_R = (P_R - c_R) \cdot [Q_E(P_E(P_R)) + Q_U(P_R) - q_U]. \tag{33}$$

Knowing the function $P_E(P_R)$, defined by equation (32), Russia maximises its profit from equation (33) by choosing the optimal price of gas sold to Ukraine. Then, assuming linearity of demand functions for the Russian gas in Europe and Ukraine, from equation (32), we obtain

$$P_E = \frac{1}{2}\cdot\left(\frac{a_E}{b_E} + c_{UT} + P_R\right).$$

Maximisation of Russia's profit [equation (33)] with respect to (P_R) yields the following prices of the Russian gas in Europe and Ukraine, respectively:

$$P_R^* = \frac{\frac{1}{2}\cdot a_E + a_U - q_U + \frac{1}{2}\cdot(c_R - c_{UT})\cdot b_E + c_R\cdot b_U}{b_E + 2\cdot b_U},$$
$$P_E^* = \frac{\frac{3}{2}a_E\cdot b_E + \frac{1}{2}(c_R + c_{UT})\cdot b_E^2 + b_E\cdot b_U\cdot(c_R + c_{UT}) + b_E\cdot(a_U - q_U) + 2a_E\cdot b_U}{2b_E\cdot(b_E + 2b_U)}. \quad (34)$$

Thus, total Russia's profit will be

$$\pi_R^* = (P_R^* - c_R)\cdot(a_E - b_E\cdot P_E^* + a_U - q_U - b_U\cdot P_R^*).$$

5. Russia delivers its Europe-bound gas to the Russian–Ukrainian border

Yet another option of selling Russian gas to Europe is its delivery to the Russian–Ukrainian border, while transporting this gas via Ukrainian territory is agreed upon by Ukraine and Europe. Note that in this case (as in a previous one), Russia is, according to a Stackelberg model, a leading player. Let Russia, following the policy of price discrimination, set different gas prices for Europe and Ukraine P_{ER} and P_U, respectively. The price of Russian gas in Europe will be $P_E = P_{ER} + \tau$, where τ—the transportation tariff charged by Ukraine. Then, Russia's profit from supplying gas to Europe and Ukraine will be as follows:

$$\pi_R = (P_{ER} - c_R)\cdot Q_E(P_{ER} + \tau) + (P_U - c_R)\cdot[Q_U(P_U) - q_U].$$

Ukraine's profit from transporting Russian gas to Europe is

$$\pi_U = (\tau - c_{UT})\cdot Q_E(P_{ER} + \tau).$$

Ukraine sets transportation tariff that maximises its profit, which yields the following FOC:

$$Q_E(P_{ER} + \tau) + (\tau - c_{UT})\cdot Q_E'(P_{ER} + \tau) = 0. \quad (35)$$

The equation (35) defines transportation tariff as a function of P_{ER}, i.e. $\tau(P_{ER})$. Knowing the function $\tau(P_{ER})$, Russia maximises its profit from gas supplies to Europe, which yields

$$Q_E(P_{ER}+\tau(P_{ER}))+(P_{ER}-c_R)\cdot Q_E'[1+\tau'(P_{ER})]=0. \tag{36}$$

Equation (36) defines the optimal for Russia value of P_{ER}.

For a linear European demand for Russian gas function, the following optimal values of transportation tariff and prices of Russian gas at the Russian–Ukrainian border and in Europe are obtained:

$$P_{ER}^{*}=\frac{1}{2}\left(\frac{a_E}{b_E}+c_R-c_{UT}\right),$$

$$\tau_{*}=\frac{1}{4}\left(\frac{a_E}{b_E}+c_R-c_{UT}\right),$$

$$P_E^{*}=\frac{1}{4}\left(3\frac{a_E}{b_E}+c_R+c_{UT}\right).$$

From maximisation of Russia's profit from supplying gas to Ukraine, one obtains, for a linear function of Ukrainian demand function for gas, the optimal for Russia values of P_U^* and Q_U^* given by equation (26). Then, under considered scheme of trade, Russia's total profit will be as follows:

$$\pi_R^{*}=(P_{ER}^{*}-c_R)\cdot(a_E-b_E\cdot P_E^{*})+(P_U^{*}-c_R)\cdot(Q_U^{*}-q_U).$$

6. Cooperation of Russia and Ukraine

Up to now, when analysing different schemes of trade, it has been assumed that Russia and Ukraine behaved non-cooperatively. Consider next a case of cooperative behaviour of Russia and Ukraine. In this case, the coalition could aim at maximising total social welfare that includes profit from selling Russian gas to Europe, Ukrainian gas consumer's surplus, profit from selling Russian gas to Ukraine and profit of Ukrainian gas companies, i.e. solving the following problem:

$$\max_{P_E,P_U}\left\{W=(P_E-c_R-c_{UT})\cdot Q_E(P_E)+\int_{P_U}^{\infty}Q_U(\xi)d\xi\right.$$
$$\left.+(P_U-c_R)\cdot[Q_U(P_U)-q_U]+(P_U-c_{UE})\cdot q_U\right\}. \tag{37}$$

Solving the problem (37) yields the following results:

$$P_E^{*}=\frac{1}{2b_E}[a_E+b_E\cdot(c_R+c_{UT})],$$

$$Q_E^{*}=\frac{1}{2}[a_E-b_E\cdot(c_R+c_{UT})],$$

$$P_U^* = c_R,$$
$$Q_U^* = a_U - b_U \cdot c_R.$$

Then, the maximum social welfare of Russia and Ukraine (under the condition $C_R > C_{UE}$), will be equal to

$$W = \frac{(a_U - b_U \cdot c_R)^2}{2b_U} + \frac{1}{4b_E} \cdot [a_E - b_E \cdot (c_R + c_{UT})]^2 + (c_R - c_{UE}) \cdot q_U,$$

where the first term corresponds to Ukraine's gas consumers surplus at the price of Russian gas equals to marginal costs of its production and transportation, the second, to the profit from selling Russian gas to Europe and the third, to the profit of Ukrainian gas companies.

The benefits for Russia and Ukraine from cooperation depend on the existing non-cooperative trading scheme as well as on bargaining power of each participant. In case of equal bargaining power, according to a Nash solution, each of the participants gets half of an additional (relative to the corresponding non-cooperative scheme) total benefit from cooperation.

7. Estimation of trading schemes efficiencies

To estimate the efficiency of the trading schemes, one needs to know the parameters of demand functions and marginal costs. Coefficients of demand functions, equations (7) and (23), have been calculated from the data on gas consumption by Ukraine and 25 European countries Q_{U0} and Q_{E0} and the corresponding prices P_{E0} and P_{U0} in 2005 under assumption that price elasticities of demand for gas in 2005 in Europe and Ukraine were equal to –0.5 and –0.3, respectively. Under these assumptions, $a_E = 357 \cdot 10^9$ cu m, $b_E = 0.94 \cdot 10^{12}$ (cu m)^2/\$, $a_U = 95\ 10^9$ cu m, $b_U = 0.21 \cdot 10^{12}$ (cu m)^2/\$, $q_u = 18.8 \cdot 10^9$ cu m. Long-term marginal costs of gas production and transportation in Russia have been assumed to equal C_R = \$40/10^3 cu m (Tarr and Thomson, 2003). Marginal cost of transporting Russian gas via Ukraine C_{UT} = \$5.14/10^{3}cu m (Observatoire Mediterranien de l'Energy, 2002). Marginal cost of natural gas production in Ukraine C_{UE} = \$10/10^3 cu m.

Estimation results are presented in **Table 1**, where the following notations of different trading schemes have been used:

1. I.0: actual state of affairs at present;
2. I.1: Russian gas is sold to Europe at the Ukrainian western border, according to the existing long-term contracts. The tariff for transporting Russian gas supplied via Ukraine and the price of Russian gas supplied to Ukraine are set independently of each other;

Table 1 Characteristics of different trading schemes

	I.0	I.1	I.2	II.1	II.2	III	IV	V
Transportation tariff ($\$/10^3$ cu m)	15	210	0	172.5	95.6	89.7	88.8	—
Gas price for Ukraine ($\$/10^3$ cu m)	105	201.4	0	201.4	186.4	205.0	201.4	40
Gas price in Europe ($\$/10^3$ cu m)	250	250	250	296.1	257.7	295.2	296.1	212.5
Supplies of Russian gas to Europe (10^9 cu m/year)	120	120	120	78.6	114.8	79.5	78.7	157.3
Supplies of Russian gas to Ukraine (10^9 cu m/year)	54.1	33.9	95	33.9	37.1	33.0	33.9	86.6
Russia's profit from gas sales to Europe ($\$10^9$/year)	23.4	0	25.2	6.57	14.0	—	13.2	—
Russia's profit from gas sales to Ukraine ($\$10^9$/year)	3.5	5.47	−3.8	5.47	5.4	—	5.5	—
Russia's total profit ($\$10^9$/year)	26.9	5.47	21.4	12.0	19.4	18.6	18.7	—
Ukraine's profit from transportation of Russian gas to Europe ($\$10^9$/year)	1.2	24.6	−0.62	13.1	10.4	6.7	6.6	—
Total profit of Russia and Ukraine from gas sales to Europe ($\$10^9$/year)	24.6	24.6	24.6	19.7	24.4	—	19.8	26.3
Ukrainian gas consumer's surplus ($\$10^9$/year)	12.6	6.6	21.5	6.6	7.4	6.4	6.6	17.9
Ukraine's social welfare ($\$10^9$/year)	15.6	34.8	20.8	23.3	21.1	16.8	16.8	—
Total social welfare of Russia and Ukraine ($\$10^9$/year)	42.5	40.3	42.3	35.3	40.5	35.4	35.5	44.8

3. I.2: Russian gas is sold to Europe at the Ukrainian western border, according to the existing long-term contracts. The price of Russian gas, supplied to Ukraine, is defined as a function of transportation tariff ($P_U = \alpha\tau^2$);
4. II.1: Russian gas is sold to Europe at the western Ukrainian border, under Russian monopoly on the residual European market demand. The price of Russian gas, supplied to Ukraine, and transportation tariff are set independently of each other;
5. II.2: Russian gas is sold to Europe at the western Ukrainian border, under Russian monopoly on the residual European market demand. The price of Russian gas, supplied to Ukraine, is defined as a function of transportation tariff ($P_U = a \cdot \tau$);

6. III: all Russian gas is sold to Ukraine, the latter deciding how much gas to consume and how much to re-export to Europe;
7. IV: Russian gas is sold to Europe at the border between Russia and Ukraine;
8. V: Russia and Ukraine form a coalition to maximise total social welfare.

The trading scheme in which Ukrainian demand for gas function is characterised by constant price elasticity, and Ukraine consumes only Russian gas, is not included in Table 1. This is explained by incompatibility of initial assumptions of this trading scheme and all the others. Nonetheless, the results of this trading scheme are given below:

$$\alpha_* = 1.2,\ \beta_* = 1.4,\ \tau_* = \$46.2/10^3\,\text{cu m},\ P_U^* = \$40/10^3\,\text{cu m},$$
$$Q_U^* = 97.4\,\text{bn cu m/year},\ \pi_R^* = \$19.9\text{bn/year},\ \pi_U^* = \$4.9\text{bn/year}.$$

In trading scheme I.2, under practically any value of the parameter α, the optimal for Ukraine transportation tariff equals zero, and Russia's profit does not depend on α. Generally speaking, it is understandable that under high enough demand for the Russian gas in Europe (relative to the Ukraine's), one can always find such a function $P_U(\tau)$ under which the optimal value of transportation tariff will be zero. That is why direct comparison of trading scheme I.2 and II.2 is not quite correct since function $P_U(\tau)$ is different. It should be mentioned that the delegation mechanism [i.e. setting by Russia the function $P_U(\tau)$] results in much higher Russia's profit (compare I.1, I.2 and II.1, II.2). Understandably, the highest value of total profit of Russia and Ukraine from selling Russian gas to Europe is gained under cooperation of Russia and Ukraine. The lowest Russia's profit is realised when Russian gas is sold to Europe on European–Ukrainian border, under independently defined transportation tariff and the price of Russian gas supplied to Ukraine. Though selling Russian gas to Europe on the Russian–Ukrainian border (all other conditions being equal) is more profitable for Russia (compare options II.1, III, IV), this trading scheme deprives Russia of the possibility to enter lucrative domestic gas markets in Europe. From Table 1, it can be seen that the main results of trading schemes III and IV are rather close, which, according to equations (26) and (34), is coincidental. It should be noted that trading scheme I.2 is close to a cooperative one.

One of the most important results of comparing different trading schemes is that under the actually existing agreements on supplies of Russian gas to Europe and Ukraine, Russia gets the highest profit. This result indicates that while striking agreements with Russia on supplies of Russian gas to Europe and Ukraine, the latter does not properly benefit from its role as a monopolist transporter of Russian gas to Europe. This can be explained by low bargaining power of Ukraine in its negotiations with Russia, which, in turn, could result from the fact that the Russian–Ukrainian agreements are strongly influenced by other than purely economic factors, i.e. the threats to cut gas supplies to Ukraine, possible reaction of Europe to reduction of Russian gas supplies, political pressure Russia exerts on Ukraine (e.g. setting gas prices dependent on Ukrainian support of the Russian foreign policy), etc. Empirical estimates, based on the analysis of the Russian–Ukrainian gas relations (Klyuka, 2010), show that the bargaining power of Russia is much higher than that of Ukraine. This reasoning is supported by the events of January 2009, when Russia cut off its supplies of gas to Europe and Ukraine and the EU intervened into the Russian–Ukrainian gas conflict. The models, analysed in the paper, do not take into account these factors.

8. Conclusion

The present paper shows that under existing state of affairs, the profit Russia gets from the natural gas trade with Europe and Ukraine is much higher compared with that dictated purely by economic considerations. This suggests that Ukraine does not take adequate advantage of its monopolistic position in trade of Russian gas to Europe. This can be explained by the low bargaining power of Ukraine in its negotiations with Russia, which, in turn, could result from the fact that the Russian–Ukrainian agreements are strongly influenced by political factors, which are not taken into account in the analysed models.

The use of the delegation mechanism, i.e. setting the price of supplied to Ukraine gas, dependent on the transportation tariff, set by Ukraine, proves to be an effective tool for Russia and results, other things being equal, in substantially higher profits.

In case Russia supplies gas to Europe, using its monopoly power on residual European gas market demand, the best trading scheme for Russia is selling its gas to Europe on the Russian–Ukrainian border. However, this trading scheme deprives Russia of the possibilities to enter lucrative domestic gas markets in Europe.

Note

1. Here and thereafter, the discussion focuses on Ukraine; however, it applies to Belarus as well.

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