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The export of Russian gas to Europe: breaking up the monopoly of Gazprom

Abstract:
Having exports from more than one Russian gas producer has been an important issue in the Russian–EU energy dialogue during the last decade. Nevertheless, in June 2006, Russian Federal law legalized the *de facto* export monopoly of Gazprom. Political and commercial interests have regularly explained the Russian strategy for the European gas market. However, it is important that economic efficiency is also taken into account. Economists often evaluate the efficiency of a policy through its effect on national welfare. In this paper, I examine both theoretically and numerically whether a liberalization of Russian gas exports would increase Russian national welfare, given that the Russian domestic market is already deregulated. The results of the paper show that the dominant position of Gazprom in the Russian gas industry might stimulate the government to support Gazprom's export monopoly. The market share of independent producers in the Russian gas market would have to be significantly increased for Russian export liberalization to be welfare enhancing.

Keywords: Russia, Natural gas, export, monopoly, national welfare

JEL classification: D43, D60, L13, Q38

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1. Introduction

Exports from more than one Russian gas producer would bring more competition into the European gas market. This has been an important issue in the Russian–EU energy dialogue during the last decade. Nevertheless, in June 2006, Russian Federal law gave the Russian gas company Gazprom an exclusive right to export natural gas to Europe. Gazprom's direct ownership of all high-pressure gas transmission pipelines in Russia has already given Gazprom a *de facto* export monopoly, which it has had since its establishment in 1993. Thus, the new law does not affect the structure of Russian supply to Europe. Rather, it legalizes the *status quo* and has thwarted EU's efforts to bring competition into Russian supply to the European gas market. It also prevents other Russian gas producers, whose share of Russian gas production has steadily grown and reached about 17% by 2005, from exporting gas to Europe, at least into the near future.

Political interests and Gazprom's commercial interests are central in Russia in the context of exporting natural gas to Europe. However, in this paper, I show that Gazprom's export monopoly might be economically efficient for Russia.

Assuming that Russian national welfare is the main concern of the Russian government, I examine both theoretically and numerically whether a liberalization of Russian gas exports and the breaking up of Gazprom's export monopoly could benefit Russia. In its concern for national welfare, it is assumed that the government ignores the effect of export liberalization on foreign firms and consumers, and cares only about the domestic consumer surplus and the profits earned by national firms in domestic and export markets.

Russian gas pricing policy has to some extent justified Gazprom's export monopoly. Gazprom has always been obliged to sell gas at regulated prices, which were historically low and barely covered long-run marginal costs. Other Russian gas producers, or independent producers, as they are known in Russia, have been formally free to sell their gas at market prices. Thus, Gazprom's export monopoly has been a mechanism through which Russia has been able to ensure adequate gas supplies to the domestic market at low regulated prices. However, as the Russian economy began to recover, the Russian government gradually began to increase gas prices in Russia. Gazprom argues that the deregulation of Russian gas prices should be the next step in the reform of Russian gas prices. According to Gazprom's view of Russian gas market developments published in 2003 (Gazprom 2003), increased supply from independent producers and imports from Central Asia will create

adequate competition for Gazprom in the Russian domestic gas market when the market is deregulated.

Deregulation of the Russian gas price frees Gazprom of the burden of domestic cross-subsidization and eliminates the need to rationalize Gazprom's export monopoly. With the exclusive right to export natural gas to Europe, Gazprom can appropriate all export profits and, hence, can increase its competitive advantage over independent producers. Thus, it is worth investigating whether the legalization of Gazprom's export monopoly to Europe remains justified.

First, I analyze the problem theoretically. I consider a two-country model in which one homogeneous good is traded separately in the domestic and foreign countries, but only the domestic country can export to the foreign country. By using comparative static analysis, I compare the equilibrium of the market structure in which only one firm in the domestic country exports with the equilibrium in which all domestic firms export. I formally derive the effects of export liberalization on output, profits and national welfare.

In the second part of the paper, I apply the theoretical model to the Russian gas industry and calibrate the model numerically. The starting point is a reference case in which Gazprom is the only Russian producer that exports natural gas to Europe. In the Russian gas market, Gazprom competes with independent producers, and in the European gas market, Gazprom competes with other non-Russian gas exporters to Europe. The reference case is compared with one in which independent producers are also allowed to export natural gas to Europe. It is difficult to predict the size and number of Russian gas producers were Russian exports to be liberalized. Hence, I examine a hypothetical long-run equilibrium for the base year of 2005 and assume that the structure of the Russian gas market is the same as in 2005. It is then assumed that the Russian gas price is deregulated, that third party access to transmission networks is effective and that all Russian producers are free to sell at the market price.

In the theoretical and numerical analysis, I assume Cournot competition in both markets. The European gas market is oligopolistic with several large gas suppliers. In the Russian gas market, besides Gazprom, supply of natural gas comes from Russian independent gas producers and from Turkmenistan. Thus, Cournot competition, in which the firms set quantities, is a simple way of modeling imperfect competition among firms that earn nonzero profits in equilibrium in each market.

Even though the structure and the potential of the Russian gas sector have attracted the interest of both academics and politicians, there have been few, if any, previous studies that have aimed to model the effects of changes in the structure of Russian exports. Most studies have used a descriptive approach to the political and economic issues concerning the structure of exports of Russian gas to Europe; see, for example, Locatelli (2003), Ahrend and Tompson (2005) and Stern (2005). However, a number of studies use numerical models to investigate the role of Gazprom as the sole exporter of Russian natural gas, and analyze Russia's export potential to Europe, given different scenarios relating to market conditions in the Russian gas industry. von Hirschhausen et al. (2005) use a game theory approach to examine the option of transporting Russian gas to Western Europe through a new transit corridor via Belarus. Sagen and Tsygankova (2006) study the potential effects on Russian gas exports of changes in Russian domestic gas prices and production capacities.

Golombek et al. (1998) have demonstrated numerically that splitting up a single Norwegian gas exporter to the European market into two independent exporters would increase the companies' joint profits under the assumption of Cournot competition. Non-Norwegian suppliers to the European market would reduce their gas supplies in response to a splitting up of the Norwegian national exporter. This would prevent European gas prices from falling greatly and would raise Norwegian export profits. However, in Norway, there is hardly any domestic consumption. Thus, breaking up a gas exporter might be beneficial for a gas-exporting country such as Norway. In Russia, the share of natural gas in indigenous energy consumption is around 50%. Hence, a change in the export structure may affect not only the export profits Russia earns on the European market, but also domestic profits and the domestic consumer surplus.

I have not found studies in the economic literature that analyze how export liberalization in an industry can affect national welfare, given that the industry is a big supplier both to the domestic and foreign markets. However, in the international trade literature, there are a number of studies that, under different oligopolistic scenarios and assumptions about cost functions, focus on the national welfare effects of horizontal mergers when an economy is a big exporter and at the same time sells domestically (Barros and Cabral 1994; Sørgard 1997; Head and Ries 1997, Zhang and Chen 2002). This literature seems to be the most relevant when analyzing the research question raised in the current paper. These studies consistently find that under horizontal mergers the international gains outweigh domestic consumer losses. The trade-off between domestic consumer welfare and producer profits affects the social benefits of export liberalization. However, while national mergers initially affect the

domestic market structure, export liberalization changes the structure of the export market, but leaves that of the domestic market unchanged.

The paper is organized as follows. In Section 2, I set up the basic theoretical model that is used to examine the effects of breaking up the export monopoly on output, profit and national welfare. In Section 3, I explain the reference case and model calibrations in more detail. In Section 4, with the numerical model calibrated according to the market structure prevailing in 2005, I explore the impact of allowing independent producers to compete with Gazprom in the export market. In Section 5, I relax the model's calibration based on the market structure prevailing in 2005, and consider other scenarios relating to the market structures in Europe and Russia. Section 6 concludes the paper.

2. Theoretical model

I consider a two-country model in which one homogeneous good is traded separately in a domestic country and a foreign country. In the domestic country, D, there are two firms, g and n, competing with each other.[1] In the foreign country, F, there is a foreign firm, f, competing with firms from country D. Firm f does not sell outside its own market. Let y_g and y_n be the volumes that firms g and n sell to the domestic market, respectively, and let x_g and x_n be the volumes that firms g and n export to country F, respectively. Let the volume that firm f sells within country F be denoted by x_f. Let the inverse domestic demand function be $P_D = P_D(y_g + y_n)$ and let the inverse foreign demand function be $P_E = P_E(x_g + x_n + x_f)$. I use C_i to denote the cost function for firm i ($i=g, n, f$). There are decreasing returns to scale in each firm; that is, $\partial^2 C_i(y_i + x_i) / \partial(y_i + x_i)^2 > 0$. Importantly, the firms' levels of efficiency may differ.

The profits of the three firms can be written as:

$$\pi^g = P_D(y_g + y_n)\, y_g + P_E(x_g + x_n + x_f)\, x_g - C_g(y_g + x_g), \tag{1}$$

$$\pi^n = P_D(y_g + y_n)\, y_n + P_E(x_g + x_n + x_f)\, x_n - C_n(y_n + x_n), \tag{2}$$

$$\pi^f = P_E(x_g + x_n + x_f)\, x_f - C_f(x_f). \tag{3}$$

Let x_n in (1) to (3) be a parameter determined by the export policy of the domestic country that corresponds to the production volume that firm n is allowed to sell to market F. I aim to compare the equilibrium of the market structure in which only domestic firm g can export to the foreign country F

[1] To draw parallels with the Russian gas industry, g and n denote Gazprom and non-Gazprom, respectively.

with the equilibrium in which both domestic firms g and n can export. Initially, exporting by firm n is not allowed by the regulator and, at the outset, $x_n = 0$. In the new equilibrium, x_n is positive and the regulator does not set x_n above the level that firm n would choose (for example, $x_n \leq x_n^*$, where x_n^* is optimal exports for firm n).

A move to the new equilibrium can be represented by the integral of small changes dx_n. Such a small change can be referred to as an "infinitesimal increase in exports" by firm n. The easiest way of comparing the two market structures in terms of outputs, prices and national welfare is to analyze how an infinitesimal increase in exports by firm n affects the initial equilibrium.

Suppose that firms choose quantities to maximize their profits. The first-order conditions yield the following Cournot–Nash equilibrium:

$$\pi^g_{y_g} = \frac{\partial \pi^g}{\partial y_g} = P_D' y_g + P_D - C_g' = 0, \tag{4}$$

$$\pi^n_{y_n} = \frac{\partial \pi^n}{\partial y_n} = P_D' y_n + P_D - C_n' = 0, \tag{5}$$

$$\pi^g_{x_g} = \frac{\partial \pi^g}{\partial x_g} = P_E' x_g + P_E - C_g' = 0, \tag{6}$$

$$\pi^f_{x_f} = \frac{\partial \pi^f}{\partial x_f} = P_E' x_f + P_E - C_f' = 0. \tag{7}$$

The second-order conditions are as follows:

$$\pi^g_{y_g y_g} \leq 0, \pi^n_{y_n y_n} \leq 0, \pi^g_{x_g x_g} \leq 0, \pi^f_{x_f x_f} \leq 0.$$

To examine the effect of opening the foreign market to firm n, I totally differentiate the first-order conditions (4) to (7):

$$\pi^g_{y_g y_g} dy_g + \pi^g_{y_g y_n} dy_n + \pi^g_{y_g x_g} dx_g = 0 \tag{8}$$

$$\pi^n_{y_n y_g} dy_g + \pi^n_{y_n y_n} dy_n + \pi^n_{y_n x_n} dx_n = 0 \tag{9}$$

$$\pi^g_{x_g y_g} dy_g + \pi^g_{x_g x_g} dx_g + \pi^g_{x_g x_f} dx_f + \pi^g_{x_g x_n} dx_n = 0 \tag{10}$$

$$\pi^f_{x_f x_g} dx_g + \pi^f_{x_f x_f} dx_f + \pi^f_{x_f x_n} dx_n = 0. \tag{11}$$

Denoting the comparative static effects of x_n on the equilibrium output by $\widetilde{X}_i$, equations (8) to (11) can be written as:

$$\begin{pmatrix} \pi^g_{y_g y_g} & \pi^g_{y_g y_n} & \pi^g_{y_g x_g} & 0 \\ \pi^n_{y_n y_g} & \pi^n_{y_n y_n} & 0 & 0 \\ \pi^g_{x_g y_g} & 0 & \pi^g_{x_g x_g} & \pi^g_{x_g x_f} \\ 0 & 0 & \pi^f_{x_f x_g} & \pi^f_{x_f x_f} \end{pmatrix} \begin{pmatrix} \widetilde{X}_{y_g} \\ \widetilde{X}_{y_n} \\ \widetilde{X}_{x_g} \\ \widetilde{X}_{x_f} \end{pmatrix} = \begin{pmatrix} 0 \\ -\pi^n_{y_n x_n} \\ -\pi^g_{x_g x_n} \\ -\pi^f_{x_f x_n} \end{pmatrix} \tag{12}$$

It is assumed that the equilibrium is locally strictly stable, which implies that the determinant of the matrix π, on the left-hand side of (12), denoted by $|\pi|$, is positive and that, in the absence of one market, the other market would still be strictly stable. Hence, $\pi^g_{y_g y_g}\pi^n_{y_n y_n} - \pi^g_{y_g y_n}\pi^n_{y_n y_g} > 0$; $\pi^g_{x_g x_g}\pi^f_{x_f x_f} - \pi^g_{x_g x_f}\pi^f_{x_f x_g} > 0$.

In models of quantity competition, certain regularity conditions, which are the weaker stability conditions for the Cournot equilibrium, are often used (Dixit 1984; Farrell and Shapiro 1990; Clougherty and Zhang 2005). These conditions imply that the marginal revenues of each firm decrease as firm output increases. For example, for firm *g,* the marginal revenue in the home market is $y_g P_D' + P_D$. When the output of some other firm in the home market increases with y_g fixed, the regularity condition implies that $y_g P_D'' + P_D'$ is negative. Assuming that these regularity conditions hold, I define:

$\alpha \equiv y_g P_D'' + P_D' < 0$, $\quad A \equiv x_g P_E'' + P_E' < 0$,

$\beta \equiv y_n P_D'' + P_D' < 0$, $\quad B \equiv x_f P_E'' + P_E' < 0$.

Then, (12) can be written as:

$$\begin{pmatrix} \alpha + P_D' - C_g'' & \alpha & -C_g'' & 0 \\ \beta & \beta + P_D' - C_n'' & 0 & 0 \\ -C_g'' & 0 & A + P_E' - C_g'' & A \\ 0 & 0 & B & B + P_E' - C_f'' \end{pmatrix} \begin{pmatrix} \widetilde{X}_{y_g} \\ \widetilde{X}_{y_n} \\ \widetilde{X}_{x_g} \\ \widetilde{X}_{x_f} \end{pmatrix} = \begin{pmatrix} 0 \\ C_n'' \\ -A \\ -B \end{pmatrix} \tag{13}$$

From (13), it is clear that if the second-order conditions and the regularity conditions hold, and if the assumption of decreasing returns to scale is valid, all values of $\pi^j_{i_j i_j}$ (i=y ,x and j=g, n, f) in the system of equations given by (12) are nonpositive.

Effects on firms' outputs

Using Cramer's rule, I can calculate from equation (12):

$$\widetilde{X}_{y_g} = \frac{\pi^g_{y_g y_n}\pi^n_{y_n x_n}(\pi^g_{x_g x_g}\pi^f_{x_f x_f} - \pi^g_{x_g x_f}\pi^f_{x_f x_g}) - \pi^g_{y_g x_g}\pi^n_{y_n y_n}(\pi^g_{x_g x_f}\pi^f_{x_f x_n} - \pi^g_{x_g x_n}\pi^f_{x_f x_f})}{|\pi|} > 0 \qquad (14)$$

$$\widetilde{X}_{x_g} = \frac{(\pi^g_{x_g x_f}\pi^f_{x_f x_n} - \pi^g_{x_g x_n}\pi^f_{x_f x_f})(\pi^g_{y_g y_g}\pi^n_{y_n y_n} - \pi^g_{y_g y_n}\pi^n_{y_n y_g}) - \pi^g_{y_g y_n}\pi^n_{y_n x_n}\pi^g_{x_g y_g}\pi^f_{x_f x_f}}{|\pi|} < 0. \qquad (15)$$

Because the determinant $|\pi|$ is positive according to the stability condition, the signs of $\widetilde{X}_{y_g}$ and $\widetilde{X}_{x_g}$ are determined by the signs of the numerators in (14) and (15), respectively. The first component of the numerator in (14) is positive because $\pi^g_{x_g x_g}\pi^f_{x_f x_f} - \pi^g_{x_g x_f}\pi^f_{x_f x_g} > 0$ by the stability condition and because $\pi_{ij} < 0$. It is easy to show that $\pi^g_{x_g x_f}\pi^f_{x_f x_n} - \pi^g_{x_g x_n}\pi^f_{x_f x_f} < 0$,[2] and so $\widetilde{X}_{y_g} > 0$. Given that $\pi^g_{y_g y_g}\pi^n_{y_n y_n} - \pi^g_{y_g y_n}\pi^n_{y_n y_g} > 0$ by the stability condition and because $\pi^g_{x_g x_f}\pi^f_{x_f x_n} - \pi^g_{x_g x_n}\pi^f_{x_f x_f} < 0$, it is clear that $\widetilde{X}_{x_g} < 0$.

Solving (12) for $\widetilde{X}_{y_n}$ and $\widetilde{X}_{x_f}$ yields:

$$\widetilde{X}_{y_n} = \frac{-\pi^n_{y_n x_n} - \pi^n_{y_n y_g}\cdot\widetilde{X}_{y_g}}{\pi^n_{y_n y_n}} < 0 \qquad (16)$$

$$\widetilde{X}_{x_f} = \frac{-\pi^f_{x_f x_n} - \pi^f_{x_f x_g}\cdot\widetilde{X}_{x_g}}{\pi^f_{x_f x_f}} = \frac{-B(1+\widetilde{X}_{x_g})}{\pi^f_{x_f x_f}} < 0. \qquad (17)$$

[2] $\pi^g_{x_g x_f}\pi^f_{x_f x_n} - \pi^g_{x_g x_n}\pi^f_{x_f x_f} = AB - A(B + P_E' - C_f'') = -A(P_E' - C_f'') < 0.$

Because $\pi_{ij} < 0$ and $\widetilde{X}_{y_g} > 0$, it is clear that $\widetilde{X}_{y_n} < 0$. Given that $\pi^f_{x_f x_f}$ and B are negative, the sign of $\widetilde{X}_{x_f}$ is the opposite of that of $(1 + \widetilde{X}_{x_g})$, which represents the overall change in the export supply from country D. It can be shown that $(1 + \widetilde{X}_{x_g}) > 0$. (The proof is given in Appendix A.)

Equations (14) to (17) show how an infinitesimal increase in the supply of firm n to market F changes the supply of the firms to market D and market F. In the Cournot equilibrium, the response curve of each firm is downward sloping. This implies that a firm decreases its supply if its rivals increase their supplies to that market. Thus, as firm n starts to export to market F, firm g and firm f reduce their supplies to this market; that is, $\widetilde{X}_{x_g} < 0$ and $\widetilde{X}_{x_f} < 0$. Because of decreasing returns to scale, an infinitesimal increase in exports increases the average costs of firm n and, hence, firm n reduces its supply to market D; that is, $\widetilde{X}_{y_n} < 0$. When the supply of firm n to market D is reduced, firm g's output moves to a point further to the right on its domestic response curve and, hence, firm g increases its supply to market D: $\widetilde{X}_{y_g} > 0$.

Having investigated the effects of an infinitesimal increase in exports on the supply of each firm to each market, I can state the following results (proofs of which are given in Appendix A):

Lemma 1.

Allowing exports by firm n:

i) increases overall exports from country D; that is, $1 + \widetilde{X}_{x_g} > 0$;

ii) decreases the overall supply to country D; that is, $\widetilde{X}_{y_n} + \widetilde{X}_{y_g} \leq 0$;

iii) increases production by firm n; that is, $1 + \widetilde{X}_{y_n} > 0$;

iv) decreases production by firm g; that is, $\widetilde{X}_{y_g} + \widetilde{X}_{x_g} < 0$.

According to (14) to (17), changes in supply by firms g and f to both markets move in the opposite direction to supply changes by firm n. Then, parts *i)* and *ii)* of Lemma 1 imply that although the commencement of exports by firm n generates changes in the supply of firm g, the changes in each market are dominated by the supply changes of firm n. Thus, the overall changes in supply to each market move in the same direction as does the supply change of firm n. Part *iii)* of Lemma 1 implies

that although exporting by firm *n* lowers the domestic supply of firm *n,* the reduction is less than the increase in firm *n* 's exports. Part *iv)* of Lemma 1 states that firm *g* reduces its production in response to a production increase by firm *n.* Thus, allowing all firms to export from country *D* results in higher exports, lower domestic supply, lower export prices and higher domestic prices.

Effects on profits and national welfare

Now I analyze the effect of an infinitesimal change in exports by firm *n* on national welfare. I assume that the national welfare of the domestic country, denoted by *W,* consists of the surplus of domestic consumers (CS) and the profits that firms *g* and *n* earn in both markets:

$W = CS + \pi^g + \pi^n$,

where CS is the area under the inverse demand curve minus the joint income earned by firms in the domestic market:

$$CS = \int_0^{y_g + y_n} P_D(\tau) d\tau - P_D \cdot (y_g + y_n) . \tag{18}$$

Thus, the change in national welfare following an infinitesimal export increase by firm *n* can be written as:

$$\frac{\partial W}{\partial x_n} = \frac{\partial CS}{\partial x_n} + \frac{\partial \pi^g}{\partial x_n} + \frac{\partial \pi^n}{\partial x_n} .$$

Opening the export market to firm *n* lowers the overall supply to the domestic market and consequently raises the domestic price. This has a negative effect on the consumer surplus. This can be shown mathematically by differentiating (18) with respect to x_n:

$$\frac{\partial CS}{\partial x_n} = -\frac{P_D}{\varepsilon_D} \cdot (\widetilde{X}_{y_g} + \widetilde{X}_{y_n}) < 0, \tag{19}$$

where $\varepsilon_D < 0$ is the price elasticity of demand for the domestic market. From Part *ii)* of Lemma 1, the expression above is negative.

Because firm *n* will never increase its export to country *F* if it is not profitable, $\frac{\partial \pi^n}{\partial x_n}$ has to be non-negative. Thus, differentiating expression (2) for π^n with respect to x_n and utilizing (5) yields:

$$\frac{\partial \pi^n}{\partial x_n} = \frac{P_E}{\varepsilon_E} \cdot S_n \cdot (1 + \widetilde{X}_{x_g} + \widetilde{X}_{x_f}) + P_E + \frac{P_D}{\varepsilon_D} \cdot s_n \cdot \widetilde{X}_{y_g} - C'_n \geq 0 . \tag{20}$$

In (20), $\varepsilon_D < 0$ and $\varepsilon_E < 0$ are the price elasticities of demand for the domestic and export markets, respectively, while s_i and S_i (i=g, n) are national firms' initial market shares of the domestic and export markets, respectively. The first two terms in (20) constitute the marginal effect of exports by firm n on its export income. The two last terms combine the marginal effect of exports on firm n's domestic income and the marginal growth in firm n's costs. When $x_n = 0$, the first term in (20) is equal to zero ($S_n = 0$).

The effect of opening the export market to firm n on the profit of firm g, however, is less clear. Differentiating expression (1) for π^g with respect to x_n and utilizing (4) and (6) yields:

$$\frac{\partial \pi^g}{\partial x_n} = \frac{P_D}{\varepsilon_D} \cdot s_g \cdot \widetilde{X}_{y_n} + \frac{P_E}{\varepsilon_E} \cdot S_g \cdot (1 + \widetilde{X}_{x_f}). \tag{21}$$

The first term in (21) is positive; it reflects the increase in the domestic profitability of firm g following firm n's supply reduction in the domestic country. The second term in (21) is negative; it reflects the reduction in firm g's export profitability, which arises because an increase in firm n's exports raises supply to the foreign country.

Note that the respective changes in the outputs, $\widetilde{X}_i$, following increased exports by firm n depend on the initial allocation of the market shares of the firms in both markets and on the price elasticities of demand in both markets.

By summing the expressions in (19), (20) and (21) and utilizing (6), I obtain the following direct effect on national welfare:

$$\frac{\partial W}{\partial x_n} = -\frac{P_D}{\varepsilon_D} \cdot s_g \ \widetilde{X}_{y_g} + \frac{P_E}{\varepsilon_E} \cdot S_g \cdot \widetilde{X}_{x_f} - \frac{P_D}{\varepsilon_D} \cdot s_n \widetilde{X}_{y_n} + \frac{P_E}{\varepsilon_E} \cdot S_n \cdot (1 + \widetilde{X}_{x_g} + \widetilde{X}_{x_f}) + (C_g' - C_n'). \tag{22}$$

In (22), the first two terms are positive and the two next terms are negative. The sign of the last term in (22) is determined by the difference of marginal costs between firm g and firm n. When $x_n = 0$, the fourth term in (22) is equal to zero ($S_n = 0$). Because an infinitesimal export increase by firm n simultaneously changes the output levels of all firms, it is difficult mathematically to determine the sufficient conditions under which exports by firm n are welfare enhancing. Although equation (22) is not conclusive, it highlights the trade-offs between the determinants of national welfare. Reduced supply by firm n to the domestic market increases the domestic price and negatively affects domestic

welfare, but this effect is mitigated because firm *g* increases its domestic supply. On the other hand, although increased supply to country *F* reduces the export price and negatively affects country *D*'s export profit, reduced supply by firm *f* mitigates this effect. Finally, if firm *n* is marginally more efficient than firm *g*, it will positively add to the effect on the national welfare.

Note that the assumption of non-constant marginal production costs is important in the model. If marginal costs are constant, an infinitesimal export increase by firm *n* does not affect the domestic country and national welfare only changes because the joint profits of exporting firms change. In this case, $\widetilde{X}_{y_g} = 0$ and $\widetilde{X}_{y_n} = 0$ and, given an initial x_n of zero, according to (22), an infinitesimal export increase raises national welfare. Thus, the firms' supply changes following the commencement of exports by firm *n* depend on the convexity of the cost functions. For example, the more convex is the cost function of firm *n*, the greater is the reduction in domestic supply following an export increase. This means that $\widetilde{X}_{y_n}$ is larger in absolute terms. On the other hand, the more convex is the cost function of firm *g*, the smaller is the absolute level of $\widetilde{X}_{x_g}$. In response to an infinitesimal export increase by firm *n,* the reduction in exports by firm *g* is more moderate the more convex is the cost function of firm *g*. This is because each unit reduction in supply lowers marginal costs.

3. Empirical model

The theoretical model described above formally demonstrates the trade-offs between the gains and losses made by different economic agents when all national firms are allowed to export. However, there were difficulties in reaching qualitative conclusions about when gains outweigh losses. Thus, quantitative analysis is used to assess the conditions under which allowing Russian independent producers to export could increase Russian national welfare. In this section, an empirical model of the Russian gas industry is presented and analyzed. The starting point of the empirical analysis is a *reference case*, in which Gazprom is the only producer that can supply the two markets: the Russian domestic market and the European export market. In the Russian gas market, Gazprom competes with independent producers, and in the European gas market, Gazprom competes with other large gas-producing countries. The reference case and calibration of the model are explained in detail in the following subsections.

Gas consumption

Essentially, Russian natural gas is currently sold on two markets: the domestic Russian gas market and the European gas market. In 2005, Russia supplied natural gas to almost all countries in Europe that are net importers of natural gas, including not only current EU countries, but also Commonwealth Independent States (CIS) countries. While Gazprom sells its gas at market prices to Western European countries, prices for Russian gas in the CIS, and in some Eastern European countries, are low because of bilateral agreements. However, EU enlargement and the Russian–Ukrainian conflict over gas prices that raged in January 2006 indicate a movement towards market pricing in the whole of Europe in the long run. The focus of the model is restricted to consumption in two regions: Europe and Russia. Thus, gas consumption in different European countries is aggregated into consumption in a single European market.

Demand

For the calibration of natural gas demand in Europe and Russia, I use 2005-data for gas prices and consumption levels (see BP 2006). There is little consensus in the literature about price elasticities in energy markets, and there are hardly any estimates of elasticities for Russia. According to the survey of price and income elasticities of natural gas demand by Al-Sahlawi (1989), long-run price elasticities of demand range from –0.56 to –4.6. Because of the lack of decisive evidence, I have chosen a value for the price elasticity of natural gas demand in Europe of –0.7. This is consistent with other studies that model the European gas market (see, for example, Golombek et al. 1995)

The only known estimates of elasticities for Russia are found in an econometric study by Solodnikova (2003). She finds no significant link between natural gas consumption in Russia and the price of gas. This result can be partly explained by low natural gas tariffs relative to other energy carriers. As natural gas remains the cheapest energy source in Russia, a price change may have little effect on consumer behavior. In addition, the Russian energy infrastructure was built under the Soviet planned economy and allowed few substitution possibilities between energy alternatives; hence, many consumers continue to rely on one energy carrier. Nevertheless, some studies use price elasticities of around –0.5 for natural gas demand in Russia; see, for example, Holtsmark and Mæstad (2002) and Tarr and Thomson (2004). Assuming that future domestic market reforms will increase substitution possibilities between energy carrier alternatives, so that consumers will respond to gas price variations, I choose a price elasticity of demand for Russia of –0.4. This figure is between the estimates obtained by Solodnikova (2003) and those from later studies.

In Section 5, I present sensitivity analysis based on other price elasticities of demand for both Europe and Russia.

Gas producers

Besides Gazprom's production, the supply of natural gas to Europe includes imports from five companies in other major gas-producing countries (two Norwegian companies, Statoil and Norsk Hydro, the Dutch Gasunie, the Algerian Sonatrach and the Nigerian National Petroleum Corporation) and indigenous European gas production. In the model, Gazprom and the five foreign companies choose their quantities to supply to Europe under Cournot competition. Indigenous European gas production, which was 172 bcm in 2005 (BP 2006), is assumed to be exogenous to the model. The exogeneity assumption is a simplification, but can be justified on the grounds that, in order to mitigate their strong dependence on importing natural gas, most European countries with their own gas production capabilities produce at their production capacities regardless of the gas price.

In the Russian domestic market, Gazprom competes with Russian independent producers. By the end of 2005, after several acquisitions and mergers in the Russian petroleum sector, four oil companies (TNK–BP, Lukoil, Surgutneftegaz and Rosneft) and two small gas companies (Novatek and Itera) accounted for almost all non-Gazprom gas production in Russia. In the empirical model, the six independent gas producers, plus Gazprom and a single supplier from Turkmenistan independently compete with each other in a Cournot fashion. Gazprom currently buys Turkmen gas under long-term contracts and resells it to Russian and CIS consumers. However, were the Russian gas market to be deregulated, as is assumed in the model, imported gas from Turkmenistan would have to be sold directly to the market in order to increase competition. In the model, Turkmenistan is treated as an independent gas producer.

Production and transportation costs

Estimated costs for Russian and non-Russian gas producers are based primarily on the data collected by the Observatoire Mediterraneen de L'Energie (OME) (2001), which predicts the average costs of producing and transporting natural gas to Europe from major gas-producing areas for the 2010–2020 period. The costs of delivering natural gas to a market depend on the extraction conditions in the producing areas as well as on the remoteness of production from the market. To approximate the marginal cost function for each gas producer in the model, I apply the general functional form used by Golombek et al. (1995):

$$C'(q)=a+b*q+d*\ln(1-q/K), \quad (23)$$

where q is the total supply of a producer, K is the producer's total production capacity, and $a > 0$, $b > 0$ and $d < 0$ are parameters. Combining information on the production capacity of the gas fields in operation during the base year 2005 with OME estimates of production costs, I calibrate the marginal cost function for each gas producer in the model.

The production capacity data used in the calibration are presented in Appendix B (Table B). In order to give a realistic long-run perspective, the production capacities used in the model are above actual production in 2005. The production capacity data incorporate data on gas fields that are about to begin production in a few years. It is assumed that incremental capacity would have been reached in 2005 if the start-up production from the new fields were to have been accelerated. The additional expenditures required for an immediate start on production from the new fields were taken into account when calibrating the cost function parameters.

For estimates of Russian gas transportation costs, I used OME data on unit transportation costs from production regions in Russia westwards as far as the Russian border with Ukraine. The transportation costs depend on the length of the transportation route. Because Russian consumers are nearer to the Russian production regions than are European consumers, the costs of transporting gas to Russian consumers were adjusted based on the average distance to the domestic market. Thus, transportation costs differ between regions of production (Nadym Pur Taz, Orenburg, Astrahan and Yamal) and between domestic and export markets. Transportation costs to Europe are increased by a transit tariff that Russia has to pay to pipe gas through Ukraine. The transit tariff is estimated to US$17.84/1000m^3.[3]

4. Breaking up the export monopoly of Gazprom

In the reference case, only one company, Gazprom, is allowed to export. However, if Gazprom's export monopoly is removed and independent Russian producers are allowed to export to Europe, the market outcomes change. To analyze whether the opening of export markets to all Russian gas producers would benefit Russia, I determine the Cournot–Nash equilibrium in which all Russian producers can freely supply natural gas to both markets.

[3] In January 2006, tariffs for the transit of Russian gas through Ukraine were US$1.60/1000m^3 per 100 km. The distance from the Russian–Ukrainian border to Uzhgorod, the westernmost town in Ukraine near the border with Slovakia, is 1115 km (OME 2001). Thus, the estimated transit cost through Ukraine is US$17.84/1000m^3.

Table 1 shows the outcome following the break up of Gazprom's monopoly in the export market.

Table 1. Effects of breaking up the natural gas export monopoly in Russia

	Reference case	**Several Russian exporters**
Price in Europe of natural gas (US$/1000 m^3)	***189.74***	***181.67***
Total supply to European market (bcm)	659.91	686.02
Amount of total produced by:		
Gazprom	227.45	223
independent gas producers	0	31.24
non-Russian producers	432.47	431.77
Price in Russia of natural gas (US$/1000 m^3)	***130.06***	***155.19***
Total supply to Russian market (bcm)	244.95	228.24
Amount of total produced by:		
Gazprom	64.82	65.48
independent gas producers	180.12	162.76

As independent producers enter the export market, Gazprom and its non-Russian competitors slightly reduce supply to Europe. On the other hand, because of additional exports from independent producers, the total supply of natural gas to the European market increases by 4% (relative to the reference case), and the price in Europe falls. In the Russian domestic market, however, the entry of independent producers to the export market has the opposite effect. When independent producers can supply both domestically and to the export market, their marginal costs of domestic production increase. Thus, independent producers reduce their supply domestically, and the total supply to the Russian market falls. Hence, the price of natural gas in Russia increases. Gazprom then increases domestic supply.

Breaking up Gazprom's export monopoly brings more competition into the European gas market. An increased supply and a lower price benefit European consumers. However, the effect on Russian consumers is adverse. Independent producers are the only participants in the Russian gas market to benefit from this change in market structure. For Gazprom, the loss of its monopoly position as a Russian gas exporter results in reduced export earnings. However, Gazprom earns more on the domestic market. Whether the increased competition in the Russian export market has a positive or

negative effect on Russian national welfare is determined by the trade-off between the reductions in the Russian consumer surplus and Gazprom's export profits on the one hand, and the increases in the profits of the independent producers and Gazprom's domestic profits on the other hand. Table 2 shows how Russian national welfare is affected when independent producers start to export gas to the European market.

Table 2. Breaking up Gazprom's export monopoly; changes in national welfare, $ billions

Gazprom's export profit	**Gazprom's domestic profit**	**Independents export profits**	**Independents domestic profits**	**Consumer surplus**	**National welfare**
–2.32	1.73	4.19	1.06	–5.94	*–1.28*

The results in Table 2 show that breaking up Gazprom's export monopoly lowers Russian national welfare. Although the profits jointly earned by Russian gas producers in the two markets increase, the negative effects of a fall in supply from independent producers on the consumer surplus and the reduction in Gazprom's export profit are sufficiently strong for the overall effect to be negative.

5. Other scenarios

According to Table 2, under given market conditions in Europe and Russia, a reform that abolishes Gazprom's export monopoly is not justified on the grounds of national welfare criteria. In this section, I extend the discussion by focusing on alternative market conditions generated by different assumptions about the available production capacity of Russian and non-Russian gas producers. Note that assumptions about data underlie the qualitative results of the model. Thus, when analyzing how different market conditions influence the change in national welfare as a result of opening up the Russian gas export market, it is the direction, rather than the absolute scale, of the change that is more important.

Changes in supply from non-Russian producers

When exports of Russian gas are liberalized, the profitability of the European market is an important factor for independent producers. The supply of Gazprom's rivals in Europe determines Gazprom's market power in the export market and, hence, the attractiveness of the export market to independent producers. The more attractive is the export market for independent producers, the less gas will be supplied to the domestic gas market following liberalization of Russian gas exports.

A number of factors might affect the supply of Gazprom's rivals in Europe. I choose two scenarios (Scenarios 1and 2) to illustrate how breaking up Gazprom's export monopoly might affect Russian national welfare given alternative changes in supply from non-Russian gas suppliers.

The possibility of transporting natural gas by ship opens the European gas market to exporting countries in North Africa and the Middle East. The supply of LNG to Europe from Qatar, Iran, Egypt and Libya may represent a challenge to Russia's position in the European gas market in the near future. Scenario 1 assumes an immediate start to the supply of LNG to Europe from Qatar, Iran, Egypt and Libya. Each new supplier country is modeled as a Cournot producer. Data on the maximum production capacity of these countries correspond to the projected production capacity levels for 2020 of the OME (2004), which are reported in Appendix B.

As countries' own gas resources in Europe are being depleted, European imports from other countries are increasing. Thus, a scenario in which European gas dependency on Russia grows is realistic. For Scenario 2, I assume that Europe faces a more rapid depletion of its own gas resources; that is, indigenous gas production in Europe is halved.

Table 3 shows how Russian producer profits, the Russian consumer surplus and Russian national welfare are affected under Scenarios 1 and 2.

Table 3: Alternative production capacity of non-Russian producers; changes in national welfare following the breaking up of Gazprom's export monopoly, $ billions

	Scenario description	**Gazprom's export profit**	**Gazprom's domestic profit**	**Independ. export profits**	**Independ. domestic profits**	**Consumer surplus**	**National welfare**
Base Scenario		–2.32	1.73	4.19	1.06	–5.94	*–1.28*
Scenario 1	Additional LNG supply	–0.93	0.63	2.32	0.09	–2.10	*–0.01*
Scenario 2	Europe's own gas production halved	–4.90	3.65	7.49	2.99	–12.77	*–3.54*

According to Table 3, none of the considered scenarios generate incentives for Russia to open the export market to independent gas producers. The gas price in Europe falls when competition increases in the European gas market because of the extra supply of LNG from the Middle East and North Africa. Hence, independent producers gain little from exporting. The lower is the gas price in Europe, the smaller is the effect on the initial equilibrium and the smaller is the negative effect on national welfare. Under Scenario 1, the national welfare loss falls to only $0.01 billion, which is much smaller than the $1.28 billion loss that arises under the Base Scenario. A further reduction in export profitability for Russian producers would eventually lead independent producers to stop exporting and hence, the initial equilibrium would be unaffected.

When the liberalization of Russian gas exports noticeably increases independent producers' profits, larger changes to the initial equilibrium are expected. If indigenous European gas production were halved, as is the case under Scenario 2, the shortage of gas in the European gas market would raise the price in Europe considerably. As a result, the liberalization of Russian exports would benefit independent producers by $10.48 billion, rather than by $5.25 billion, as happens under the Base Scenario. Independent producers would sacrifice substantial domestic sales in order to sell gas to the attractive export market. This would consequently raise domestic prices and increase the loss in the domestic consumer surplus to $12.77 billion. The overall result of breaking up Gazprom's export monopoly under Scenario 2, when the export market is more profitable than the domestic market, would be to reduce national welfare by $3.54 billion.

Changes in supply from Russian independent producers

Opening export markets to independent producers would increase Gazprom's dominance of the Russian domestic market. The higher is Gazprom's market power at home, the more negatively are Russian consumers affected by a small reduction in supply from independent producers. Here, I investigate how breaking up Gazprom's export monopoly would affect Russian national welfare, given changes in the initial supply levels of independent producers. Table 4 shows how national welfare is affected for another two scenarios (Scenarios 3 and 4).

In recent years, Gazprom has signaled its interest in the resources of independent producers. In 2005, Gazprom took control of the Russian gas producer NorthGaz, and bought the Russian oil company Sibneft. Since 2001, Gazprom has gradually been forcing Itera out of the market. For Scenario 3, I assume that Gazprom further increases its production capacity and acquires all producing assets of Itera's productive assets. Thus, the production capacity of independent producers is reduced.

If independent producers were able to supply more gas domestically, Gazprom's dominance of the domestic market would be reduced. Then, when the export market is opened for all Russian gas producers, the reduction in the consumer surplus will not be that strong. For Scenario 4, I investigate a hypothetical case in which Gazprom sells some of its productive assets to independent producers. For this scenario, I assume that the initial production capacity of Gazprom and the initial total production capacity of independent producers are exchanged for each other. Thus, Gazprom's production capacity is reduced to the initial total production capacity of independent producers, and the production capacity of each independent producer is increased in proportion to its initial capacity so that the total production capacity of independent gas producers under Scenario 4 is equal to Gazprom's initial production capacity.

Table 4. Alternative production capacity of Russian independent gas producers; changes in national welfare following the breaking up of Gazprom's export monopoly, $ billions

	Scenario description	**Gazprom's export profit**	**Gazprom's domestic profit**	**Independ. export profits**	**Independ. domestic profits**	**Consumer surplus**	**National welfare**
Base Scenario		–2.32	1.73	4.19	1.06	–5.94	*–1.28*
Scenario 3	Gazprom buys Itera	–1.73	1.71	3.12	1.33	–6.02	*–1.58*
Scenario 4	Exchanged production capacity	–11.24	2.56	22.58	–4.06	–3.75	*6.09*

According to Table 4, the initial allocation of gas resources between Gazprom and independent producers can give an indication of whether a reform that opens the export market to all Russian producers would be welfare enhancing. When Gazprom acquires Itera's production assets, as under Scenario 3, Gazprom's market power in the domestic market increases and Gazprom has additional gas resources available for exports. Under Scenario 3, there will be an immediate domestic price increase and a reduction in the European gas price, compared with the Base Scenario. Hence, the European gas market becomes less attractive to independent producers. With fewer independent producers under Scenario 3, the overall gain made by independents from exporting is less than the gain made under the Base Scenario. However, when independent producers withdraw part of the supply from the highly monopolized domestic market, and thereby further increase Gazprom's dominance of the Russian domestic market, the loss in the consumer surplus is greater than that under the Base Scenario. The

overall result of breaking up Gazprom's export monopoly under Scenario 3 is to reduce national welfare by $1.58 billion.

The liberalization of Russian gas exports under Scenario 4 has positive effects on Russian national welfare. Under Scenario 4, gas resources are allocated more evenly between Russian gas producers, and Gazprom's market power in the domestic market is considerably lower than under the Base Scenario. Thus, when independent producers withdraw part of their supply from the domestic market in order to export to Europe, the negative effect on the consumer surplus is more moderate. The overall effect of the export reform under Scenario 4 is to increase Russian national welfare by $6.09 billion.

Changes in price elasticities

The price elasticity of demand is an important determinant of supply to a market under oligopoly. Elastic demand stimulates producers to supply more, whereas under inelastic demand, producers supply less. Thus, it is important to examine how a change in the elasticities incorporated in the numerical model would affect the results, particularly given the uncertainty about the exact values of the elasticities.

Figure 1 shows how breaking up Gazprom's export monopoly affects Russian national welfare when the elasticity parameters vary within the range from –0.2 to –2. The solid line in Figure 1 illustrates how Russian national welfare depends on the European price elasticity of demand. The dotted line in Figure 1 illustrates how Russian national welfare depends on the Russian price elasticity of demand.

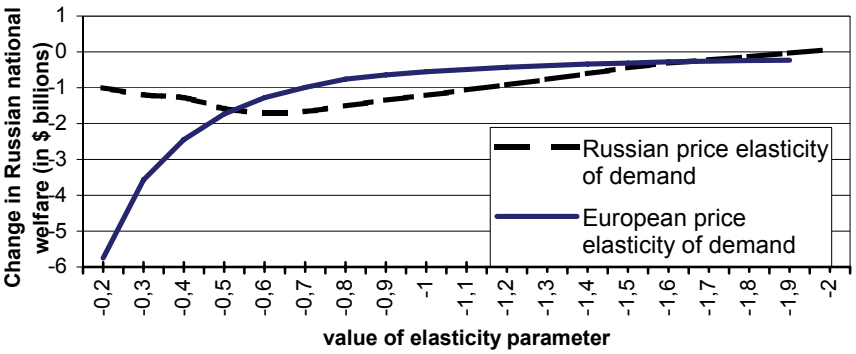
According to Figure 1, the more elastic is European demand, the less negative is the effect on national welfare. The more elastic is the European market, the more gas is supplied to Europe by Gazprom and non-Russian gas producers and, hence, the lower is the gas price in Europe. The low European price makes the European market less attractive to independent producers when they are allowed to export. Thus, the more elastic is the European market, the less gas is supplied by independent producers to Europe and the smaller is the reduction in Russian domestic supply following export liberalization. Hence, the smaller is the effect on national welfare.

Figure 1 shows that the effect of price elasticity on the change in national welfare is more complicated. When the Russian price elasticity is low, the effect on national welfare becomes more negative as the Russian price elasticity increases. However, as the domestic price elasticity increases further, the

effect on national welfare becomes less negative. When Russian demand is highly elastic, export liberalization has a positive effect on national welfare.

A possible explanation of the pattern represented by the dotted line in Figure 1 is as follows. The less elastic is domestic demand, the lower is domestic supply and, hence, the higher is the gas price in Russia. Thus, the Russian market is more attractive to independent producers and export liberalization results in ,respectively, relatively low exports and relatively small reduction in domestic supply of independent producers. Further increases in the domestic demand elasticity cause an increase in exports by independent producers and generate a larger reduction in independent producers' supply levels at home. However, when the domestic demand elasticity is relatively low and Gazprom restricts its supply to the Russian market, Russian consumers are more vulnerable to a reduction in supply from independent producers. The overall effect is that export liberalization has a more negative effect on national welfare. However, as domestic demand becomes more elastic, Gazprom's power in the domestic market is reduced, and Russian consumers are less adversely affected when independent producers withdraw part of their domestic supply following the opening of export markets. Thus, the overall effect of export liberalization on national welfare becomes less negative.

Figure 1: Changes in national welfare for different values of the elasticity parameters



Constant marginal costs

The assumptions made about the parameters of the marginal cost functions are also important for the quantitative conclusions of the paper. Thus, it is worth checking how the model's outcomes are affected by changes in the marginal cost functions. Hence, I run a version of the model in which each firm has constant marginal costs. Each firm's constant marginal costs are set equal to the cost of the

last unit of output, according to the reference case for the Base Scenario. Table 6 shows the results for the changes in the profits of Russian producers, Russia's consumer surplus and national welfare.

Table 6: Breaking up Gazprom's export monopoly; changes in national welfare, $ billions; the case of constant marginal costs

Gazprom's export profit	**Gazprom's domestic profit**	**Independents export profits**	**Independents domestic profits**	**Consumer surplus**	**National welfare**
–1.56	1.89	4.47	1.25	–6.57	*–0.51*

The modification made to firms' marginal costs does not change the finding of a negative effect of Russian export liberalization on national welfare. Under the new marginal costs, the positive effect on the total profit of Russian producers is higher and the negative effect on the consumer surplus is higher, relative to the outcomes under the Base Scenario (see Tables 5 and 6). Overall, the new results suggest a less negative effect on national welfare. Constant marginal costs stimulate independent producers to withdraw more gas from the domestic market when exports are liberalized. This increases the total profit of Russian producers and reduces the consumer surplus. In equilibrium, the production capacity of independent producers is binding. This is why export liberalization affects the domestic market when marginal costs are constant.

6. Conclusions

The results presented in this paper can help to explain the futile efforts of the EU to force Russia to introduce competition into the Russian supply side in the European gas market. Exports of natural gas to Europe from Russian producers other than Gazprom will result in an increased supply of natural gas to Europe. This will push the European gas price downwards and thus benefit European consumers who will consume more gas at lower prices. By contrast, Russian consumers will be negatively affected by a policy that abolishes Gazprom's monopoly in the export market. This will force the domestic price upwards and Russian consumers will be provided with less natural gas at higher prices. Under the current structure of the Russian gas market, in which Gazprom has a dominant position, the overall effect of Russian export liberalization on national welfare will be negative. Gazprom must reduce its dominance of the Russian gas industry before exports by independent producers can become welfare enhancing. Thus, the results of the paper show that the dominant position of a single company in the industry might justify the government's support for this company's exporting monopoly.

The recent development in the Russian gas market, under which Gazprom is gradually buying up the production assets of independent producers and thereby strengthening its dominance of the Russian gas industry, can also to some extent be understood by the results of the paper. As the Russian government follows a strategy of gradually increasing the regulated domestic gas price for Gazprom, it reduces the burden on Gazprom to provide domestic subsidies. Being the only Russian gas exporter, Gazprom earns additional rent in the export market. This gives Gazprom a substantial competitive advantage over independent producers. Because opening the export market to independent producers will negatively affect the Russian economy, and hence is not supported by the government, a merge with Gazprom may be the best way for other Russian gas producers to earn profits in the Russian gas business.

The assumption that the Russian gas market is deregulated and that all Russian gas producers sell at market prices underlies the results of the paper. Currently, this is only formally true for independent producers, while Gazprom is required to sell at regulated prices that barely cover Gazprom's long-run marginal costs. However, until the domestic price is deregulated or at least significantly raised, Russia has no choice but to control its gas exports. Otherwise, independent producers will export as much as they can while neglecting the domestic market. However, in this paper, I investigated the welfare effects of Russian export liberalization under the current structure of the domestic gas market. Given Gazprom's current dominance of the industry, deregulation of the Russian gas price will significantly raise domestic gas prices. Given that the Russian government has historically protected Russian consumers against high energy prices, the relevance of the deregulation assumption may be criticized. However, Gazprom has repeatedly put forward reform proposals to deregulate Gazprom's domestic gas prices. Recent developments in the Russian gas industry have strengthened Gazprom and suggest that Gazprom might have the political and economic power to implement its "reform plans" for survival. Another argument supporting the modeling of a deregulated domestic gas market is that it is difficult to observe and even more difficult to predict the real price at which both Gazprom and independent producers sell gas to Russian consumers. According to a survey by the OECD (2004), in 2003, 39% of industrial customers reported paying more than the regulated price for gas, but 90% of those buying some of their gas at higher prices reported buying all of their gas from Gazprom (Stern, 2005).

It is also important to stress that numerical results are based on a number of simplifying assumptions, particularly about Cournot competition between producers in both markets, and on the choice of data sources that are used in the calibration of the model. The problem of missing data is commonplace for

many numerical studies of Russian energy markets and is not unique to this study. Therefore, the results of this study cannot be used to predict the consequences of Russian export liberalization. However, they do help to explain the motivation behind Russian export liberalization and offer a quantitative example of the problem.

Export liberalization is not the only way to allocate export profits equitably between Russian gas producers. If Russian gas producers form an export cartel in the European gas market, this cartel could maximize Russia's export profits and, at the same time, more Russian gas would be available to domestic consumers. However, there is a risk that cooperative behavior in the export market spills over to the domestic market. Allocating the export profits that Gazprom earns in Europe between all Russian gas producers in proportion to their production volumes is another alternative to compensating independent producers. The Russian Antimonopoly Committee made such a proposal after Federal law gave Gazprom an exclusive right to export natural gas to Europe in June 2006. However, Gazprom's reluctance to share export profits with independent producers may reduce Russian gas exports and promote further monopolization of the Russian gas industry. The effect of the participation of Russian independent gas producers in the Russian gas export market has not been thoroughly investigated. Hence, further analysis of different structures of Russian gas exports is needed.

Appendix A

Lemma 1.

Allowing firm *n* to export will:

i) increase total exports from country *D*; that is, $1 + \widetilde{X}_{x_g} > 0$;

ii) decrease the overall supply to country *D*; that is $\widetilde{X}_{y_n} + \widetilde{X}_{y_g} \leq 0$;

iii) increase production by firm *n*, that is, $1 + \widetilde{X}_{y_n} > 0$;

iv) decrease production by firm *g,* that is, $\widetilde{X}_{y_g} + \widetilde{X}_{x_g} < 0$.

Proof

i) To prove that $1 + \widetilde{X}_{x_g} > 0$, I summarize the expression for $\widetilde{X}_{x_g}$ in (15) by using the fact that

$$1 = \frac{|\pi|}{|\pi|}.$$

$$1 + \widetilde{X}_{x_g} = \frac{|\pi|}{|\pi|} + \frac{(\pi^g_{x_g x_f}\pi^f_{x_f x_n} - \pi^g_{x_g x_n}\pi^f_{x_f x_f})(\pi^g_{y_g y_g}\pi^n_{y_n y_n} - \pi^g_{y_g y_n}\pi^n_{y_n y_g}) - \pi^g_{y_g y_n}\pi^n_{y_n x_n}\pi^g_{x_g y_g}\pi^f_{x_f x_f}}{|\pi|}$$

Because $|\pi|$ is positive, the sign of the numerator in the sum above determines the sign of $1 + \widetilde{X}_{x_g}$.

Computing the determinant $|\pi|$ and writing all $\pi^j_{i_j i_j}$ in terms of (13), after some rearrangements, it follows that:

$$sign(1+\widetilde{X}_{x_g}) = sign(|\pi| + (\pi^g{}_{x_g x_f}\pi^f{}_{x_f x_n} - \pi^g{}_{x_g x_n}\pi^f{}_{x_f x_f})(\pi^g{}_{y_g y_g}\pi^n{}_{y_n y_n} - \pi^g{}_{y_g y_n}\pi^n{}_{y_n y_g})$$

$$-\pi^g{}_{y_g y_n}\pi^n{}_{y_n x_n}\pi^g{}_{x_g y_g}\pi^f{}_{x_f x_f}) = sign[\,(\alpha P_D - 2\alpha C_n'' + P_D\beta + P_D'^2 - P_D' C_n'' -$$

$$-\beta C_g'' - P_D' C_g'' + C_g'' C_n'')(BP_E' - BC_g'' + P_E'^2 - C_g'' P_E' - C_f'' P_E' + C_f'' C_g'') +$$

$$+(BC_g'' + C_g'' P_E' - C_f'' C_g'')(C_f'' C_n'' - \beta C_g'' - P_D' C_g'' - \alpha C_n'')\,]. \qquad \text{(A1)}$$

(A1) is the sum of two terms, and each term is the product of two bracketed terms. It is possible to verify that all elements of the first term are positive. If one opens the brackets, then all elements in the second term cancel each other out, and only the positive elements of the first term remain. Hence, $1 + \widetilde{X}_{x_g} > 0$.

ii) Cramer's rule yields the following expression for $\widetilde{X}_{y_n}$:

$$\widetilde{X}_{y_n} = \frac{\pi^g_{y_g x_g}\pi^n_{y_n y_g}(\pi^g_{x_g x_f}\pi^f_{x_f x_n} - \pi^g_{x_g x_n}\pi^f_{x_f x_f}) - \pi^g_{y_g y_g}\pi^n_{y_n x_n}(\pi^g_{x_g x_g}\pi^f_{x_f x_f} - \pi^f_{x_f x_g}\pi^g_{x_g x_f}) + \pi^g_{y_g x_g}\pi^n_{y_n x_n}\pi^g_{x_g y_g}\pi^f_{x_f x_f}}{|\pi|}$$

As $|\pi|$ is positive, the sign of $\widetilde{X}_{y_n} + \widetilde{X}_{y_g}$ depends on the sum of the numerators in the expression above and (14), which after some algebraic manipulation, can be written as:

$$\begin{aligned} sign(\widetilde{X}_{y_n} + \widetilde{X}_{y_g}) = sign[\, & AP_D'P_E'(C_n''-C_g'') - AC_f''P_D'(C_n''-C_g'') + BC_n''P_D'P_E' \\ & + C_n''P_D'(P_E')^2 - C_n''C_f''P_D'P_E' - BC_g''C_n''P_D' - C_g''C_n''P_D'P_E' + C_g''C_n''C_f''P_D' \\ & - BC_g''C_n''P_E' - C_g''C_n''(P_E')^2 + C_g''C_n''C_f''P_E'\,]. \end{aligned} \tag{A2}$$

If $C_n'' \geq C_g''$, all terms in (A2) are negative and, hence, $sign(\widetilde{X}_{y_n} + \widetilde{X}_{y_g}) < 0$. Otherwise, all terms in (A2), except the first two, are positive, and it is eminently plausible that $sign(\widetilde{X}_{y_n} + \widetilde{X}_{y_g})$ is negative.

iii) The proof of *iii)* is similar to the proof of *i)*.

$$1 + \widetilde{X}_{y_n} = \frac{|\pi|}{|\pi|} + \frac{\pi^g_{y_g x_g}\pi^n_{y_n y_g}(\pi^g_{x_g x_f}\pi^f_{x_f x_n} - \pi^g_{x_g x_n}\pi^f_{x_f x_f}) - \pi^g_{y_g y_g}\pi^n_{y_n x_n}(\pi^g_{x_g x_g}\pi^f_{x_f x_f} - \pi^f_{x_f x_g}\pi^g_{x_g x_f}) + \pi^g_{y_g x_g}\pi^n_{y_n x_n}\pi^g_{x_g y_g}\pi^f_{x_f x_f}}{|\pi|}$$

$$\begin{aligned} sign(1 + \widetilde{X}_{y_n}) = sign[\, & (AP_E' - 2AC_f'' + P_E'B + P_E'^2 - P_E'C_f'' - C_g''P_E + C_g''C_f'')(\alpha P_D' + P_D'\beta \\ & + P_D'^2 - C_g''\beta - C_g''P_D') + (APC_g''\beta - C_g''\beta C_f A - B\beta C_g'^2 - BP_D'C_g'^2 - P_E'\beta C_g'^2 \\ & - P_E P_D C_g'^2 + C_f''C_g'^2\beta + C_f''C_g'^2 P_D)\,] \end{aligned} \tag{A3}$$

(A3) is the sum of two terms, and each term is the product of two bracketed terms. It is possible to see that all elements of the first term, which is the product of two bracketed terms, are positive. If one opens the brackets, then all elements in the second term will cancel each other out and only the positive elements of the first term remain. Hence, $1 + \widetilde{X}_{y_n} > 0$.

iv) Summarizing the expression for $\widetilde{X}_{y_g}$ in (14) and that for $\widetilde{X}_{x_g}$ in (15) yields:

$$\widetilde{X}_{y_g} + \widetilde{X}_{x_g} =$$

$$\frac{(\pi^g_{x_g x_f}\pi^f_{x_f x_n} - \pi^g_{x_g x_n}\pi^f_{x_f x_f})(\pi^g_{y_g y_g}\pi^n_{y_n y_n} - \pi^g_{y_g y_n}\pi^n_{y_n y_g} - \pi^g_{y_g x_g}\pi^n_{y_n y_n}) + \pi^g_{y_g y_n}\pi^n_{y_n x_n}(\pi^g_{x_g x_g}\pi^f_{x_f x_f} - \pi^g_{x_g x_f}\pi^f_{x_f x_g} - \pi^g_{x_g y_g}\pi^f_{x_f x_f})}{|\pi|}$$

$$\begin{aligned} sign(\widetilde{X}_{y_g} + \widetilde{X}_{y_n}) = sign[&(AC_f'' - AP_E')(\alpha P_D' + P_D'\beta + P_D'^2 - \alpha C_n'' - C_n'' P_D') + \\ &+ (-\alpha C_n'')(BP_E' + AP_E' + P_E'^2 - AC_f'' - C_f'' P_E)] \end{aligned} \qquad \text{(A4)}$$

(A4) is the sum of two terms, and each term is the product of two bracketed terms; all elements are negative in the first bracket and positive in the second bracket. Thus, the two terms are negative and, hence, $\widetilde{X}_{y_g} + \widetilde{X}_{x_g} < 0$. Q.E.D.

Appendix B

Table B: Firm's production capacities (parameter K in the marginal cost function (23))

Russian gas producers		**Non-Russian gas producers**	
Producer	*Parameter K*	*Producer*	*Parameter K*
Gazprom	622	Statoil	79
Novatek	30	Norsk Hydro	28
Itera	25	Gasunie	50
TNK–BP	27	Sonatrach	80
Surgutneftegaz	15	Nigerian National Petroleum Corporation	24
Lukoil	17		
Rosneft	20	*Libya**	35
Turkmenistan	60	*Egypt*	28
		Qatar	45
		Iran	30

Note: * Production from Libya, Egypt, Qatar and Iran is not incorporated in the model for the Base Scenario. Production from these countries is only modeled under Scenario 1.

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