ELSEVIER

Energy Policy 36 (2008) 867–880

ENERGY POLICY

www.elsevier.com/locate/enpol

Russian natural gas exports—Will Russian gas price reforms improve the European security of supply?

Eirik Lund Sagen*, Marina Tsygankova

Statistics Norway Research Department, Kongensgt. 6, N-0033 Oslo, Norway

Received 3 April 2007; accepted 26 October 2007

Abstract

In this paper we use both theoretical and numerical tools to study potential effects on Russian gas exports from different Russian domestic gas prices and production capacities in 2015. We also investigate whether a fully competitive European gas market may provide incentives for Gazprom, the dominant Russian gas company, to change its export behaviour. Our main findings suggest that both increased domestic gas prices and sufficient production capacities are vital to maintain Gazprom's market share in Europe over the next decade. In fact, Russia may struggle to carry out its current long-term export commitments if domestic prices are sufficiently low. At the same time, if Russian prices approach European net-back levels, Gazprom may reduce exports in favour of a relatively more profitable domestic market.

Keywords: Russia; Export; Gas price

1. Introduction

The European dependence on Russian natural gas has been and continues to be an important issue. As a consequence, both political and economic aspects of the gas-related issues between the two regions have been thoroughly discussed in the literature; see e.g. Quast and Locatelli (1997), Oostvoorn et al. (1999), Finon and Locatelli (2002), Tarr and Thomson (2004) and Stern (1995, 2005). In relation to the deregulation of the European energy markets, the European Union (EU) has extensively focused on security of supply issues, see EC (2000, 2006), and perhaps above all on the potential of rising Russian market shares combined with unreliable supplies to the European gas market.[1] Russia's state-controlled company, Gazprom, is the largest single source of natural gas to Europe, and in 2005 Gazprom alone covered almost 30% of the total European gas demand (BP, 2006).

This study builds on a viewpoint that it need not necessarily be turmoil between Russia and its transit countries that is the largest threat to both large and stable Russian gas supplies to Europe. In contrast to the European concern about Russian market shares, there have recently been studies pointing out that Russia for several reasons may not be the stable and dominant provider of gas that Europe for a long time has been accustomed to, see e.g. Stern (2005) and Spanjer (2006). These studies argue that particularly insufficient production capacity may have a negative impact on future export volumes. Russia currently struggles with undefined depletion rates for several giant operating gas fields and there are question marks related to the ability to compensate for the observed production decline, at least within the next decade. In addition, the same studies reveal that if Russian gas prices approach international market levels, Europe may no longer be the preferred selling market for Russian gas producers.

The EU has long claimed that Russia should raise their strongly regulated domestic gas price towards European

*Corresponding author. Tel.: +47 21090000; fax: +47 21094963.
E-mail addresses: eirik.lund.sagen@ssb.no (E.L. Sagen), marina.tsygankova@ssb.no (M. Tsygankova).

[1] This concern attained much attention after the Russia–Ukraine price dispute in January 2006, which threatened to obstruct gas flows to Europe, see WGI (2006).

0301-4215/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enpol.2007.10.030

price levels, which historically have been up to ten times higher. This view has also been adopted by the Russian government following its negotiations to join the WTO, see Stern (2005), and a Russian price reform will effectively reduce the competitive advantage of the Russian industry utilising low-cost fuel inputs. In addition, it could also lead to additional export volumes towards Europe as Russian gas demand respond to higher prices. However, there are major uncertainties related to both the speed and the effect of the Russian gas price reform. Needless to say, if Russian gas price reforms fail, the possibility of scarce production capacity may be a major challenge for Gazprom in terms of reaching its export targets, while at the same time serving the huge domestic gas market at possible very low regulated prices. In this paper we take these discussion points further by analysing the following research questions within a numerical modelling framework:

1. What effect will different domestic gas prices have on future Russian gas export volumes?
2. To what extent will the production capacities of Gazprom and other Russian gas producers affect export volumes and the allocation of sales between domestic and export markets?
3. How may radical changes in the Gazprom export volumes tied to long-term contracts (LTCs) affect the allocation of total sales between domestic and European export markets?

Using a numerical optimisation model, Gazprom allocation model (GAZALMOD), we study explicitly the effects on Gazprom's optimal allocation of gas sales between domestic and export markets for a range of Russian domestic gas price levels in 2015. A central assumption in this study is that the current status of the Russian gas market structure will prevail for at least the next 8 years. That is, Gazprom as a state-controlled company will meet obligations to serve the domestic market at any price if necessary. Furthermore, we assume that Gazprom continues to have both sole export rights to Europe[2] and de facto control of third party access to transmission pipelines connecting independent producers to the domestic market.

At the European market Gazprom competes primarily with the two other major exporters, Algeria and Norway. Hence, we look at exports from these players as a Cournot game at the European spot market, leaving all other producers as price takers. However, most of the gas sales towards 2015 are expected to follow the historical LTC conditions with a firm oil price link, and real competition may therefore continue to be highly restricted. Nevertheless, in order to test for a response to potential variations in the European natural gas sales structure, we also run the model for the extreme case of no LTCs, that is, a European natural gas market solely based on gas-to-gas oligopoly competition. This type of European market structure has been discussed in several earlier studies, see e.g. Golombek et al. (1995) and Neumann and Hirschhausen (2004).

Even though both the structure and the potential of the Russian gas sector and its coherent importance to Europe have attained great interest in both academic literature and in political circles, there have been few, if any, previous studies that aim to model the quantitative effects on future Russian gas exports from changes in the Russian domestic gas industry. Consequently, most studies have used a descriptive approach to the political and economic issues concerning the relationship between the Russian and European natural gas market. While we in this study look at Gazprom as a monopolist in their domestic market and a Cournot oligopolist at the European market, Hirschhausen et al. (2005) use a game theory approach to study Russian gas exports following a bargaining game between Russia and its transit countries. An earlier study by Bjerkholt et al. (1990) looks at the supply of gas to Europe as a Bertrand game between Russia, Algeria and Norway.

The rest of this paper is organised as follows: In Section 2 we introduce our model and explain some main effects theoretically. In Sections 3 and 4 we present some central data input, the numerical assumptions and the scenarios used in this study, respectively. In Section 5 we present our simulation results and Section 6 concludes.

2. The Gazprom allocation model (GAZALMOD)

In this paper we introduce the model GAZALMOD as a tool for analysing how the gas markets in Europe and Russia may be interconnected by the dominant presence of Gazprom in both markets. GAZALMOD is a static numerical optimisation model[3], which looks at one given year, in this paper 2015, and allows quantitative analysis of the allocation of Gazprom production volumes between domestic and export markets. The main objective of the model is to investigate how different patterns of domestic gas price rises in Russia may influence future export volumes of Russian gas to Europe. We then run different scenarios of production capacities, based on the fundamental uncertainties related to the future maximum production level of both Gazprom and the independent producers.

The main player in GAZALMOD is the Russian state-controlled gas company Gazprom, which maximises its profits in both the domestic and its export markets subject to sets of constraints. A key foundation of the model is the assumption that the current Russian natural gas market structure and gas industry organisation will prevail, at least

[2]This export monopoly was formally legalised by the Russian Federal law in June 2006.

[3]The optimisation technique belongs to the mathematical programming where an objective function is maximised (minimised) subject to the set of (non-linear) constraints. The model is programmed and optimised within the GAMS programming language using the non-linear-programming (NLP) solver.

until the model year 2015. That is, the gas industry faces strong state control with regulated end user prices, and Gazprom stays a giant state-owned company preventing any real market competition through its direct ownership of all gas infrastructure. Furthermore, Gazprom faces obligations to meet the domestic demand at any price by either using its own production or allowing alternative supplies from independent producers through its pipeline system to fill the potential gap.

In Europe, LTCs will most likely occupy large portions of the export volumes in the foreseeable future. In GAZALMOD, the volume of LTCs is exogenous and inflexible in each model run; however, residual exports may be sold at spot markets with prices based on gas-to-gas competition. In GAZALMOD, the major exporters to Europe: Russia, Algeria and Norway, act as Cournot players at the European spot market, while their LTC volumes are sold at a given price related to an assumed oil price level. In addition to the supply from the Cournot players, we also include indigenous European supplies and LNG supplies from North Africa and the Middle East. The profits of total Gazprom sales are then given by the following formula:

$$\pi_G = P_D Q_D + P_C Q_C + P_E\left(Q_E + \sum Q_i\right) Q_E - C_G(Q_D + Q_C + Q_E) - w(Q_E + Q_C). \quad (1)$$

At the domestic market, Gazprom supplies Q_D at a regulated price P_D. The export market supplies are divided in to fixed LTC sales Q_C, at a price P_C, and open market sales Q_E at a price P_E, which again is the residual inverse demand as a function of Gazprom's gas sales Q_E and gas sales $\sum Q_i$ from the other competitors at the European market.

$C_G(Q_D+Q_E+Q_C)$ determines the costs of Gazprom production and transportation within Russia. C_G is an increasing convex function, hence, $C_G' \geqslant 0$ and $C_G'' \geqslant 0$. Finally, the parameter w reflects the additional transportation and transit costs per unit of gas exported outside Russia towards the European market.

The *optimal* supply from independent Russian gas producers, S_I, is a function of their production capacity, M, and the domestic price level, P_D. However, the *actual* independent production, Q_I, is in reality constrained by their variable access to the national gas transportation system, totally owned and controlled by Gazprom. Hence, Gazprom effectively dictates the level of both it's own and the independent gas production, that is, $Q_I + Q_D = D(P_D)$.

Gazprom's profit optimisation problem may then be formulated subject to a set of constraints:

$$Q_D + Q_E + Q_C \leqslant K, \quad (2)$$

$$D(P_D) - S_I(P_D, M) \leqslant Q_D, \quad (3)$$

$$Q_D \leqslant D(P_D). \quad (4)$$

In Eq. (2), the production capacity, K, limits the total supply of gas from Gazprom. Eq. (3) describes that Gazprom's domestic sales may be larger than the residual domestic demand after the profit maximising independent supply decision, S_I. The rationale behind this fact is obviously that Gazprom effectively dictates *actual* independent supplies, Q_I, by its ownership and strict control of the domestic pipeline system, as noted earlier. Consequently, we have that $Q_I \leqslant S_I\ (P_D, M)$. Eq. (4) ensures that Gazprom's supply to domestic market does not exceed total demand.

Thus, Gazprom finds a combination of Q_D and Q_E that maximises (1) subject to the constraints (2)–(4). In Appendix A we discuss the FOC's of the maximisation problem (1)–(4) and formally prove how Gazprom's supply between the domestic market and the export spot market changes as the domestic price, P_D, increases.

Given the intuition of Gazprom's maximisation problem, we introduce two threshold prices, P_D^{T1} and P_D^{T2}, that can be interpreted as the turning points at which Gazprom changes its allocation pattern. These prices are important for the further analysis of the model and are derived below.

For a given P_D we define $Q_D^*(P_D)$ and $Q_E^*(P_D)$ as an optimal solution to Gazprom's profit maximisation in the two markets (domestic and export) where marginal revenues between the domestic market and the export spot market are balanced. As the regulated price P_D increases, the relative profitability of the domestic market also increases, thus Gazprom will increase $Q_D^*(P_D)$ and decrease $Q_E^*(P_D)$. On the other hand, following an increase of the regulated price P_D, both domestic demand $D(P_D)$ and residual demand $D(P_D)-S_I(P_D)$ will fall. Thus, the threshold price P_D^{T1} is the lowest price at which Gazprom's allocation solution is not binding by (3) and the threshold price P_D^{T2} is the highest price at which Gazprom's allocation solution is not binding by (4). Hence, we define the two threshold prices P_D^{T1} and P_D^{T2} from the respective equalities of the constraints (3) and (4) above:

$$Q_D^*(P_D^{T1}) = D(P_D^{T1}) - S_I(P_D^{T1}, M), \quad (5)$$

$$Q_D^*(P_D^{T2}) = D(P_D^{T2}). \quad (6)$$

However, the constraints will at some levels of P_D force Gazprom to supply above or below its optimal and desired volumes. For any regulated price below P_D^{T1}, Gazprom' domestic supply has to exceed the optimal choice $Q_D^*(P_D)$ in order to cover domestic demand. In this case Gazprom allows access of all gas that independent producers can supply to the domestic market and then covers the residual demand. Moreover, for any regulated price above P_D^{T2}, it is optimal for Gazprom to sell more at the domestic market than the market can bear. In this case, Gazprom has to limit its domestic deliveries given the actual demand and will not allow any access of independent producers to the domestic market. For any price between P_D^{T1} and P_D^{T2} Gazprom's optimal choice $Q_D^*(P_D)$ is not constrained, neither by the domestic residual demand nor by total domestic demand. In this case Gazprom chooses its optimal allocation between the markets and allows independent producers to cover the residual domestic demand.

Thus, Gazprom's allocation of domestic gas sales $Q_D(P_D)$ at different domestic prices can be described analytically as

$$\text{For any price, } P_D < P_D^{T1},\ Q_D^*(P_D) = D(P_D) - S_I(P_D, M) > Q_D(P_D),$$
$$\text{For any price, } P_D^{T1} \leqslant P_D \leqslant P_D^{T2},\ D(P_D) - S_I(P_D, M) \leqslant Q_D(P_D) = Q_D^*(P_D) \leqslant D(P_D),$$
$$\text{For any price, } P_D > P_D^{T2},\ Q_D(P_D) = D(P_D) < Q_D^*(P_D).$$

Gazprom's sales volumes to the export market may depend on the residual volumes after domestic supplies as well as the total production capacity. Within production capacity limits, export volumes are residual after domestic supplies for $P_D < P_D^{T1}$ and $P_D > P_D^{T2}$ to the optimal point where marginal costs equal marginal revenues at the export market. For $P_D^{T1} \leqslant P_D \leqslant P_D^{T2}$ export volumes are always optimal unless restricted by the overall production capacity.

3. Data and calibrations

3.1. Costs

We base the estimates of Gazprom's cost function in the model on the estimates made by OME (2004), where the Russian supply costs for delivery to the EU29 border from different production regions are estimated for the period 2010–2020. The gas delivery costs depend on the remoteness of production from the market as well as on the extraction conditions of the fields for each production alternative.

We divide Gazprom's supply costs in two separate parts; costs of production and average transportation costs within Russia, respectively. In order to establish an approximate marginal cost function, we apply the general functional form used by Golombek et al. (1995):

$$C'(q) = a + b\,q + d\,\ln(1 - q/K), \tag{7}$$

where q is the total supply ($q = Q_D + Q_C + Q_E$), K is the production capacity, and a, b and c are parameters. Calibration of the parameters is based on actual production and transportation costs data and provides the following numerical marginal supply cost function:

$$C'(q) = 27.08 + 0.03\,q - 1.36\,\ln(1 - q/K). \tag{8}$$

Based on export duties, transit costs, and a longer transportation route of exported gas compared with domestic supplies, we include a parameter w in Gazprom's export cost function. Data from Landes et al. (2004), Gazprom Financial Report (2004) and IEA (1993) suggest the value of w to be \$45/1000 m^3.

We apply the same functional form to the marginal supply costs of independent producers as we do for Gazprom. In order to reduce the dependence on Gazprom related to gas transport, independent producers often choose their consumer markets to be relatively close to the production area, see Stern (2005). This makes the average gas transportation costs of the independent producers lower compared with Gazprom's costs. Based on cost information from the financial reports of various Russian oil companies (Yukos, TNK-BP and Lukoil) and other information on costs and future gas projects of independent producers, we calibrate the numerical cost function for independent producers to be

$$C'_N(q) = 12.05 + 0.19q - 8.1\,\ln(1 - q/K). \tag{9}$$

3.2. Elasticities and demand

There is in general little consensus in the literature concerning the price and income elasticities in energy markets, and estimated elasticities for Russia are virtually non-existing. The elasticities that have been estimated vary and are primarily obtained for member countries of the OECD. In the survey by Al-Sahlawi (1989) on price and income elasticities of natural gas demand, short-run price elasticities range from −0.07 to −0.63 and long-run price elasticities range from −0.56 to −4.6. Considering the medium-term time horizon adopted in this study, we assume a price elasticity of natural gas demand in Europe of −0.5.

The only known estimates of elasticities for Russia are found in an econometric study made by Solodnikova (2003). She finds no significant link between natural gas consumption in Russia and the price of gas. The result can be partly explained by persistently low natural gas tariffs relative to other energy carriers. As natural gas continues to be the cheapest energy source in Russia, a price change may not have a notable effect on consumer behaviour. In addition, the Russian energy infrastructure was built during the Soviet planned economy and allowed low substitution possibilities between energy alternatives, hence consumers still often have to rely on one-energy carriers. Nevertheless, some studies use price elasticities around −0.5 for natural gas demand in Russia, see e.g. Holtsmark and Mæstad (2002) and Tarr and Thomson (2004). We assume an elasticity of −0.3 in 2015, which is between the results of Solodnikova and the latter studies. Future Russian gas market reforms will most likely encourage both enhanced industrial fuel efficiency and more substitution possibilities between different fossil fuels.

We further assume the income elasticity of demand for natural gas in Russia to be 0.7, which is between the short- and long-run income elasticities estimated by Solodnikova (2003). Al-Sahlawi (1989) shows that in OECD countries, short-run and long-run estimates of income elasticities of demand vary from 0.008 to 0.9 and from 0.1 to 6.4, respectively. For simplicity reasons we assume the income elasticities of demand in Europe and Russia to be equal.

For the calibrations of natural gas demand in Europe and Russia we use 2005 data for gas prices, consumption levels and GDP levels, see BP (2006), Rosstat (2006) and IMF (2006) and projections for GDP in Europe and in Russia by 2015, see EIA (2006).

Changes in the elasticities used in the model will obviously have an impact on the numerical results. The best indicator of this may be the changing values of the threshold prices, described in Section 2. In the discussions we will elaborate more on the sensitivities of changing elasticity values.

4. Numerical assumptions and scenario descriptions

4.1. The domestic price reform

Since 2000, Russian industrial natural gas prices have been raised by 10–20% annually in nominal terms. However, for the period 2000–2006 real price growth was positive only in two separate years; 14% and 5% in 2004 and 2005, respectively. Calculating in 2006 prices and 2006 exchange rates, the domestic gas price increased from \$31/1000 m^3 in 2000 to \$37/1000 m^3 in 2006. However, in Russia as in Europe, there is growing attention on bringing Russian gas prices towards international market levels. Taking into account the regular downward adjustments of earlier projected domestic price increases and the fear of inflationary pressure, we adopt a modest view on the projected price development in our model. Hence, taking into account great uncertainties concerning the future domestic price level, we run the model with a domestic price range for 2015 (in 2005 prices using constant exchange rates) of \$37–180/1000 m^3 for all potential production capacity scenarios, summed up in Table 1. This range includes the possibilities of both total price reform failure as well as Russian average prices reaching international netback values.

4.2. The production capacity of Gazprom

In 2006, Gazprom's production was 548 billion cubic metres (bcm), and that was higher than the target Gazprom publicly stated some years before—namely to achieve and maintain annual natural gas production levels at 530 bcm through 2010, see IEA (2002). The uncertainty concerning further gas field developments in Russia, which is related to both economic and physical constraints, has been one reason for fairly modest projections. The risk of future production capacity shortage has been indicated for several years already, see e.g. Oil & Gas Journal (2001) and Petroleum Economist (2002).

The three West Siberian giant gas fields, Medvezhye, Urengoy and Yamburg, currently accounting for over 60% of Gazprom's production, have all reached their decline phase of production, see Stern (2005). Moreover, there are major uncertainties related to how the future decline rates for these fields will develop. The Siberian giant fields are unique and they have already experienced different patterns of production decline. Uncertain physical characteristics, related to both the overall field size and the development in field pressure, make the future decline rates of these fields highly uncertain (see Stern, 2005; EIA, 2002).

The largest developed gas field in the European part of Russia is Orenburg; however, this gas field is also in its decline phase. According to estimates by Landes et al. (2004), production from the Russian satellite fields might be doubled during the next decade under favourable economic conditions.

The giant Shtokman gas field in the Barents Sea and the Siberian Yamal Peninsula fields, primarily represented by the giant Yamal Bovanenko, have both vast gas deposits. Difficult mining conditions require huge upfront investments; hence the projected production start-up from both these fields has been repeatedly delayed. As it is projected today, e.g. in Landes et al. (2004), production from Yamal might start between 2010 and 2015 at the earliest, which is also indicated in Stern (2005). For the Shtokman field, changing signals from Gazprom regarding both a potential international joint partnership and whether or not to produce LNG from Shtokman gas may indicate a delayed production start-up from even this giant gas field. Depending on the priorities of Gazprom and the Russian state, it is reasonable that at best only one of the giant projects will deliver gas before 2015, and then most likely with fairly small volumes in the start-up phase. If Shtokman is utilised for LNG, Europe may not even be the destination market. Our conjecture is therefore that by 2015, primarily smaller associated satellite fields in the West-Siberian Nadym-Purtaz region will compensate for the inevitable production decline from the existing fields.

Due to the huge uncertainties regarding the physical field characteristics of the most central producing gas fields in Russia, we choose to run different scenarios of production capacities rather than modelling the capacities endogenously based on pure cost estimates. This decision is further supported by the current political influence that seems to be growing in the Russian gas industry, which may have a direct or indirect effect on the strategic decisions related to future up-stream developments. In this paper we look at three plausible scenarios of Gazprom's production capacity in the model. We choose the current estimated production capacity at 550 bcm as our base case scenario, and production capacities of 500 and 600 bcm represent the pessimistic and optimistic scenarios, respectively.

Table 1
Adopted production capacity scenarios (bcm)

	Gazprom's production capacity ("gaz")	Independent gas producers production capacity ("ind")
Low	500	100
Base	550	130
High	600	160

4.3. Independent producers production capacity

In 2005 independent producers (smaller gas companies and oil companies with associated gas) accounted for only 14% (roughly 94 bcm) of total Russian production. However, it is assumed that the independents have proven reserves to increase their production volumes substantially. A number of oil companies have indicated that they are willing to boost both utilisation of associated gas and production from their pure gas fields if they are guaranteed access to markets, see Landes et al. (2004) and WGI (2005a). Novatek, currently the largest independent gas company, supplied 5% of Russia's domestic gas market in 2005, and a forecasted production growth indicates that this company alone may be able to reach a production level of 50 bcm already by 2010, see WGI (2005b).

According to "Russia's Energy Strategy through 2020" (2003), the volume of "independent gas" at the domestic market may reach 120–135 bcm per year by 2015. But even though the production potential of independent producers is high and the investment shortage is not an obstacle, independent producers are reluctant to initiate new projects that will increase their production capacity as long as Gazprom controls the market access through its pipeline ownership. On the other side, even if Gazprom opens up for competition, which is not very likely at this date, the independent producers will still need several years to develop their potential capacities. In this study we consider three scenarios for independent producer's production capacity in 2015: 100, 130, and 160 bcm, respectively. Higher independent capacities also imply larger volumes of cheap (associated) gas available to the domestic market; hence, the independent supply costs curve is also affected when capacities increase. All Gazprom and independent production capacity scenarios are summarised in Table 1.

4.4. The CIS gas market

The main CIS importers of Russian gas are Ukraine and Belarus, consuming roughly 85% of Russian gas exports to the former Soviet republics. Although Gazprom repeatedly argues for international market prices for all its customers, the dependence on gas transit through Ukraine and Belarus to reach western markets provides these countries with significant bargaining power in the price negotiations with Gazprom. Hence, prices for Russian gas in CIS markets are generally higher than in Russia, but still considerably lower than prices paid in Europe.

The production potential in the CIS, particularly in Turkmenistan and Uzbekistan, is substantial. However, Gazprom controls practically all pipelines connecting CIS production to other consumer markets. Hence, Gazprom can purchase e.g. Turkmeni gas to carry out its own delivery commitments related to exports or its domestic customers. Nevertheless, in 2005 the CIS countries produced 172 bcm of gas, while the same countries consumed 194 bcm (BP, 2006), which means that Russia was a net supplier to the region.

Especially Turkmeni gas production is expected to grow substantially in the near future, reflected by the highly disputed purchase agreements between Gazprom and Turkmenistan, see Oil & Gas Journal (2005) and WGI (2006b). To simplify the discussions, we do not model the CIS market explicitly as we a priori assume that supply equals demand within all CIS countries. Hence, in a model perspective, all CIS production owned or controlled by Gazprom is traded inside the CIS region. A possible imbalance of CIS supply and demand will not cause any fundamental problems related to the model results or the discussions. It seems reasonable to assume that Gazprom aims to balance the costs of extracting gas from its existing fields and the costs of buying CIS gas for resale. Thus, the potential residual CIS gas supply controlled by Gazprom after CIS demand may be considered as a part of Gazprom's resource base and therefore may be included as an argument for the (optimistic) Gazprom capacity scenarios introduced above. A negative internal CIS gas balance seems less likely when considering the prospects of future production in particularly Turkmenistan. Furthermore, we expect the value of the CIS gas to be quite steady for Gazprom as a trader, since price increases in Ukraine and Belarus create arguments for the producing countries, e.g. Turkmenistan, to increase their selling price, and vice versa.

4.5. Transportation capacities

In spite of the widely discussed transit friction that Gazprom continuously faces with Ukraine and Belarus, we believe that sufficient export transportation capacity to Europe will not be any problem during the next decade, "Russia's Energy Strategy Through 2020" (2003) estimates total exports to Europe by 2015 to be somewhat lower than 160 bcm. The already existing export pipelines through Ukraine and the Yamal-Europe corridor through Belarus can carry 168 bcm of gas to Europe annually. During the next decade the Yamal-Europe pipeline is expected to expand from the current 20 bcm capacity to the initially planned capacity of 33 bcm per year. The construction of the North European Pipeline through the Baltic Sea, as a diversification alternative for Gazprom's export routes, will give at least an extra 20 bcm of export transportation capacity annually by 2015. These projects, together with an ongoing joint project by Gazprom and the Ukrainian oil and gas company NaftoGaz Ukrainy to boost export capacities through Ukraine through increased compression and pipeline repairments, can provide Gazprom a likely minimum of 225 bcm annual export transportation capacity to Europe by 2015. As the expected transport capacity seems to be well above all known export targets, we do not explicitly model any export capacity constraint; however, we report in the discussions if the modelled outcomes for Russian exports in 2015 exceed the assumed maximum transport capacity.

In 2004, the Russian domestic gas transmission system handled a total of 687 bcm, see Landes et al. (2004). This is well above Gazprom's total production that year and includes transportation of transit gas, mainly from Turkmenistan, and gas from independent producers. The effect of increasing domestic prices on domestic demand will likely further strengthen our assumption of excess capacity in the Russian transportation network towards 2015.

4.6. Long-term export contracts

A more competitive European gas market implies the entrance of new contract mechanisms, such as spot markets and short-term contracts decoupled from the traditional oil products price link. A large volume of LTCs creates heavier obligations and less flexibility for Gazprom's exports. On the other hand, the major gas producers argue that LTCs constitute a firm basis for investments and ensure financing for the capital-intensive infrastructure and field developments. Whereas LTCs remain important, their share and average contract duration will probably be gradually reduced, see Neumann and von Hirschhausen (2004). By 2015, it is argued that up to one-third of the gas traded in Europe may be sold at short-term contracts or spot markets, see Fellers (2004). Nevertheless, with today's regular contract duration of 15–25 years, a large portion of the European gas market will still be fed by existing LTCs by 2015.

In 2005, Russian exports of natural gas to Europe reached 150 bcm, and practically all this gas was sold through LTCs with prices fixed to various oil products. According to Gazprom Chief Executive Alexey Miller, Gazprom has already signed contracts that will bring 2500 bcm to Europe over the next 15 years,[4] which will imply an average of over 160 bcm per year through 2015. Hence, we use 160 bcm as the non-flexible contract volume in our model, which also corresponds to the official export estimate for 2015 in "Russia's Energy Strategy Through 2020". All exports above this level is therefore sold at European spot markets based on gas-to-gas competition.

In order to test for a response to variations in the European natural gas LTC environment, we also run the model for the extreme case of no contracts, that is, a fully competitive European natural gas market based on gas-to-gas competition. Although this seems unrealistic, it may serve as a good indicator for the effect of European gas market liberalisation on Russian gas exports.

5. Model results and discussions

In the discussions below, our aim is to highlight the model's results based on our main research questions. The fundamental assumption in all the scenarios is that Gazprom is in total control of both Russian exports to European gas markets and pipeline access to domestic markets for all producers. Furthermore, we assume that if Gazprom's production capacity is insufficient to serve its obligations at both the domestic and the European export market, the export market will be sacrificed. We saw this happen last during some very cold days in 2006, where Russian peak demand caused Gazprom to reduce its deliveries to its European customers by 10–20%,[5] see WGI (2006c).

In Table 2, we outline the mechanisms behind the model results that are discussed later in this section. Corresponding to the threshold prices introduced in Section 2, the table shows three possible phases of Gazprom and independent gas supply decisions as the domestic gas price varies from our low-end level ($37/1000 cm) to our high-end level ($180/1000 cm).

We see that for the lowest domestic prices, Gazprom generally wants to minimise the sales domestically, as indicated by phase I, that is, the domestic price is either below marginal production costs or marginal profits from domestic sales is below marginal export profits. Hence, a maximum of independent supplies is desirable, however, the low prices give no incentives for independent producers to supply at their capacity limit if the price is lower than their marginal costs of production. Consequently, Gazprom has to cover a relatively larger residual domestic demand at any cost due to their obligations as the supplier of last resort at the domestic market. For the low-end prices, the residual domestic demand is so high that Gazprom will generally use all of its residual capacity to carry out its obligations at the European export market.

At higher domestic price levels, the Russian demand response is negative, creating additional volumes for export markets. This continues up to a certain point, P_D^{T1}, where the domestic market becomes equally profitable at the margin compared with exports. At the same time Gazprom's growing supply to the European short-term market causes European prices to fall and marginal revenues at the European spot market approach the marginal costs of exports. Hence, Gazprom's supply may no longer be constrained by its production capacity, represented by phase II, indicating that Gazprom could be executing market power in Europe to keep prices high.[6] The allocation of Gazprom supplies from export markets to the domestic market due to domestic price increases

[4]Stated in a presentation at the XXIII World Gas Conference, Amsterdam, June 6, 2006.

[5]Since Gazprom faces legal obligations to carry out its European contracts over the year, and not over the day, we have yet to see a genuine challenge to these commitments.

[6]Market power behaviour may even happen at domestic prices below P_D^{T1}; however, this will be critically dependent on the European spot price level and the assumed production capacity of Gazprom. Using the current high price level of gas in the calibration of European gas demand we do not see any indications of Gazprom executing any market power in Europe, even for the optimistic production capacity cases. However, in alternative model runs, using considerably lower European market prices we have revealed some market power behaviour where Gazprom holds back production volumes.

Table 2
Different output-phases in GAZALMOD

I	II	III
Regulated domestic price level (P_D)		
$P_D < P_D^{T1}$	$P_D^{T1} \leqslant P_D < P_D^{T2}$	$P_D \geqslant P_D^{T2}$
Gazprom's supply (S) vs. Gazprom's capacity (K)		
$S = K$	$S \leqslant K$	$S = K$
Gazprom domestic supply decision		
Min. domestic $\frac{\partial Q_D}{\partial P_D} \leqslant 0$	Optimal/max domestic $\frac{\partial Q_D}{\partial P_D} \geqslant 0$	Max. domestic $\frac{\partial Q_D}{\partial P_D} \leqslant 0$
Gazprom short-term export supply decision		
Max. exports $\frac{\partial Q_E}{\partial P_D} \geqslant 0$	Optimal exports $\frac{\partial Q_E}{\partial P_D} \leqslant 0$	Max. exports $\frac{\partial Q_E}{\partial P_D} \geqslant 0$
Independent supply decision		
Optimal $\frac{\partial Q_I}{\partial P_D} \geqslant 0$	Constrained $\frac{\partial Q_I}{\partial P_D} \leqslant 0$	Constrained $Q_I = 0$

constrains the independent production level below their desired cost-based optimum. The differential between desired and constrained independent supply increases for higher domestic prices until independent supplies are no longer required. For domestic prices equal to or above P_D^{T2}, represented by phase III in Table 2, Gazprom will cover the entire Russian gas market alone. Hence, once again export volumes are residual and increasing for higher domestic prices due to Russian demand reductions.

Obviously, the realisation and timing of these model phases may depend on the various combinations of capacity constraints that are applied in this study or whether we look at a LTC or a spot price dominated European gas market. The discussions below will sum up the main findings concerning the allocation of Gazprom's supplies when faced with the different capacity scenarios and the European LTC environments applied in this study.

5.1. Production capacities and export performance in a LTC environment

In order to isolate the effects on Russian exports from changes in the domestic price and Gazprom's production capacity, we keep the level of independent production capacity constant at a medium level of 130 bcm. Fig. 1 shows total exports towards Europe for medium (550 bcm), high (600 bcm) and low (500 bcm) Gazprom production capacities in 2015 as a function of the domestic price range applied in this study.

As higher domestic prices restrain domestic demand in Russia, a larger export potential is created, early described as the "Russian natural gas bubble" in Stern (1995). We find that the Russian domestic natural gas demand shrinks by roughly 210 bcm if the domestic price is increased from $37 to $180 per 1000 cm in 2015. This is a strong indication that Russian domestic gas price reforms alone may have a substantial effect on the total amount of Russian gas sold at the European market. However, due to profit maximisation in both domestic and export markets and the supply of independent producers, it is not a one-way relationship between domestic demand reductions and export growth.

When export markets are more profitable, Gazprom will allow maximum independent domestic supplies at any domestic price. However, for the low domestic prices, independent supplies are constrained by their own cost function and Gazprom has to cover domestic demand as the supplier of last resort. We observe that if Russian gas price reform fails and domestic prices are in the lower range, Gazprom is unable to carry out its assumed export contract obligations of 160 bcm in 2015 and Russia is obviously severely behind its future export targets.[7] This holds even for Gazprom's optimistic production capacity scenario of 600 bcm per year.

When the domestic price increases, demand is reduced and independent producers find it profitable to sell more gas. This creates larger volumes of exports for Gazprom, and in the base and high capacity scenarios exports may exceed 250 bcm. Hence, the transport capacity to Europe may be a binding constraint for a certain combination of high production capacity and moderately high Russian gas prices. However, increasing domestic prices also moves the marginal profitability of gas sales in favour of the domestic market to the point where the marginal profitability of the domestic and the export market is equal, referred to as phase II in Table 2. This turning point is characterised by the threshold domestic gas price P_D^{T1} in our theoretical examination. We see this clearly in Fig. 1, as export volumes start to fall when the domestic prices are sufficiently high due to the balance of marginal profits between the domestic and export markets. The threshold price P_D^{T1} for the high-capacity case is $80/1000 cm, while the threshold price is larger for lower production capacities due to the negative price response in the European market when Russian exports increase (exports is residual after domestic sales for prices below P_D^{T1}). For prices higher than P_D^{T1} Gazprom will reallocate gas from export to domestic markets as the latter market becomes more profitable. This will eventually squeeze independent producers out of business, and Gazprom will finally cover the domestic market alone at the domestic threshold price P_D^{T2}, described as phase III in Table 2.

From the discussions above, we clearly see that both domestic price reforms and sufficient independent gas supplies seem to be crucial for the Russian gas industry in the near future. If Gazprom is forced to give priorities to domestic market obligations, it is straightforward that Gazprom export volumes will suffer badly from the

[7]Gazprom aims to reach an export level towards Europe of at least 190 bcm per year by 2010, see WGI (2005c).

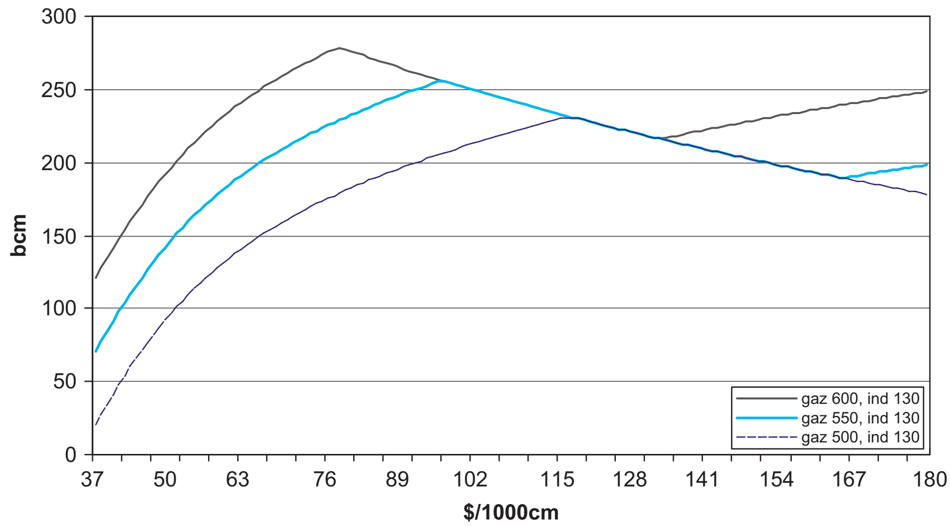

Fig. 1. Russian exports to Europe at different Gazprom supply capacities.

potential lack of supplies from alternative producers, particularly if the Gazprom production capacity is too low to compensate for the export decline itself. Fig. 2 shows the importance of independent supplies for Russian exports as we compare various combinations of Gazprom and independent production capacities at the same range of domestic price levels, holding Gazprom export contract obligations constant at 160 bcm.

If Gazprom production capacity growth is partially offset by independent capacity reductions (or vice versa), our results show that exports are generally higher for the larger Gazprom capacities. This is due to the independent producer's profitability requirements that make these producers an insufficient replacement for Gazprom domestic supplies, particularly at low domestic prices. Thus, exports may suffer if Gazprom capacities are low, even in the optimistic independent capacity alternative. However, in this case, exports will catch up with the high Gazprom capacity scenarios as domestic prices rise, due to increased profitability for the independent producers. The threshold prices P_D^{T1} and P_D^{T2} are once again dependent on Gazprom production capacities, while only the level of P_D^{T1} is dependent on independent capacities. This is a direct consequence of Gazprom's control over independent supplies. At domestic prices below P_D^{T1}, more independent supplies are needed to supply the relatively less profitable domestic market, while at P_D^{T2} independent capacities are irrelevant as the whole domestic market is covered by Gazprom.

Fig. 3 explicitly shows the volumes of independent gas supplies for the same capacity scenarios, and thus highlights Gazprom's power over independent pipeline access.

We see that Gazprom will exercise its monopoly power in the domestic market to squeeze independent supplies if domestic prices are high enough to make the domestic market profitable. This is most evident in a situation where both Gazprom and independent capacities are high. The export commitments through LTCs constrain Gazprom from occupying an even larger domestic market share.

5.2. The role of LTCs for the allocation of Gazprom supplies

In this section we will take a closer look at the potential influence on Russian exports from a changing European gas market structure towards more spot market trade and gas-to-gas competition in short term. We look at the extreme, and probably unlikely case of a no LTC environment in 2015 just to highlight the possible effect on Russian exports from changes in the European market structure. The EU aims to open up the natural gas market for more competition in all parts of the supply chain.[8] The purpose is to bring gas prices down through increased competition; however, our results show that in an oligopoly market place market players (in this case Gazprom) may want to keep volumes down to maintain higher prices.

Fig. 4 reveals that the level of gas exports tied to LTCs may prove to be highly significant for Gazprom's allocation of gas sales in the future. Our results indicate that Gazprom will reduce its exports in favour of domestic gas sales at much lower domestic prices and at lower export volumes if LTC commitments are removed.

For the lower range of Russian gas prices (below P_D^{T1}), we see that the level of contract volumes plays no role for Gazprom's overall export performance. In this case all available volumes are directed for export due to the relatively less profitable domestic market. Once again, for this price range only the production capacity is influential for export volumes. However, when the domestic market becomes equally profitable as exports (at P_D^{T1}), there is a

[8]Nevertheless, the EU has formally backed the major supplier's claim that LTCs are often necessary to bring on huge investments in new production and transportation facilities.

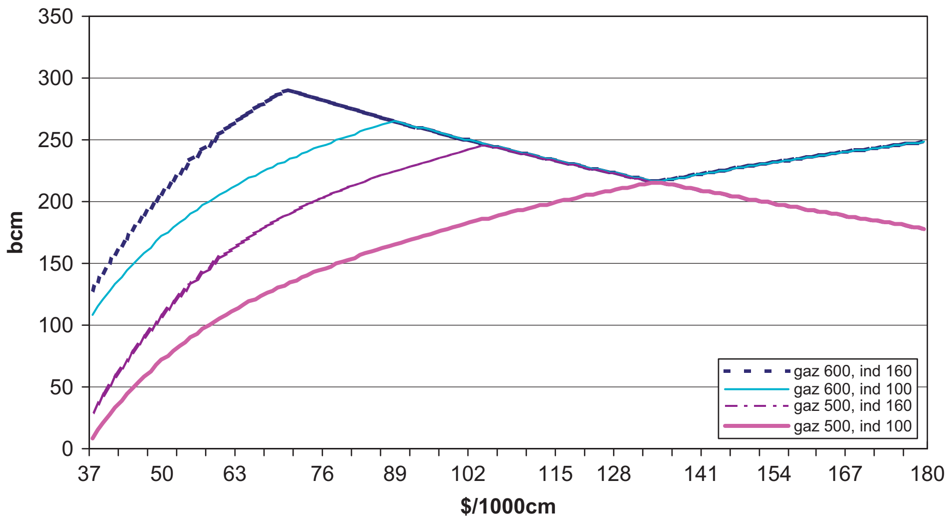

Fig. 2. Russian gas exports to Europe at different levels of independent supplies.

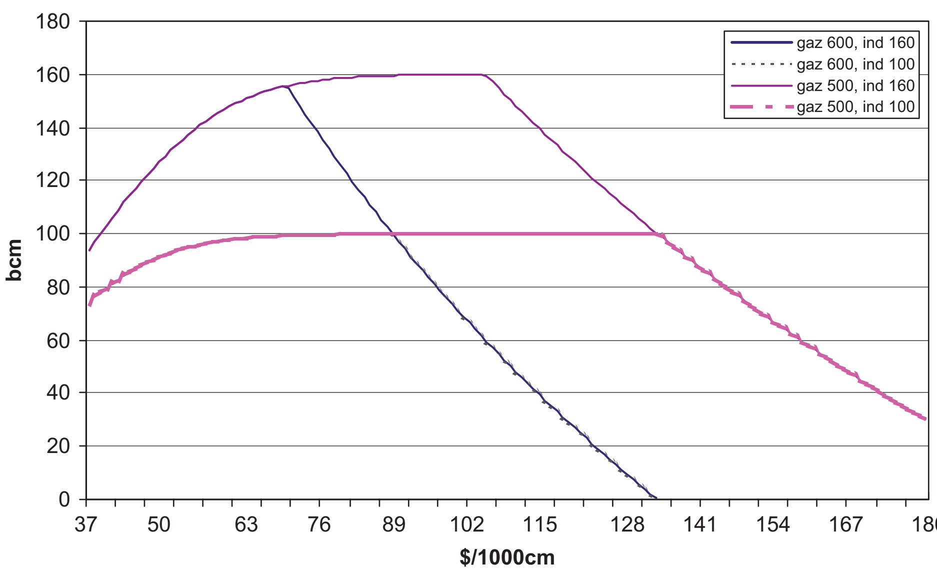

Fig. 3. Domestic supplies from independent gas producers.

growing difference in export volumes between an LTC and a no-LTC environment as domestic prices increase, shown by the bars in Fig. 4. In a fully liberalised market with no fixed contracts, market prices respond more to supply changes. Hence, the threshold price P_D^{T1} is reached at a lower level in a no-LTC environment as Gazprom exports increase, and consequently the export level is also lower at this turning price. As the domestic price increases, the export level without LTCs turns to be substantially less than exports with LTCs; however, the difference flattens out when P_D^{T1} is achieved in the scenario where LTCs are included. The export difference is then reduced steadily when Gazprom covers its domestic market alone at the threshold price P_D^{T2} in the no-LTC marketplace. Finally, we observe that only if domestic prices approach international netback levels, overall export volumes move towards the peak export levels observed in an LTC environment.

5.3. Policy implications

To summarise, our findings show that Gazprom adjusts its export volume to achieve optimal prices and revenues in its export market, and regulates independent supplies to achieve optimal revenues at the domestic market. A liberalised European export market, largely or fully determined by gas-to-gas competition, therefore seems to favour Gazprom in terms of possibilities to allocate more volumes from exports to the domestic market. This seems to be in contrast to the EU ambition of increased security of supply in a liberalised European gas market. Unless Russian gas prices move towards the netback levels of European market prices minus the cost of transport, Europe may actually have less imports of Russian gas compared with a traditional LTC market structure.

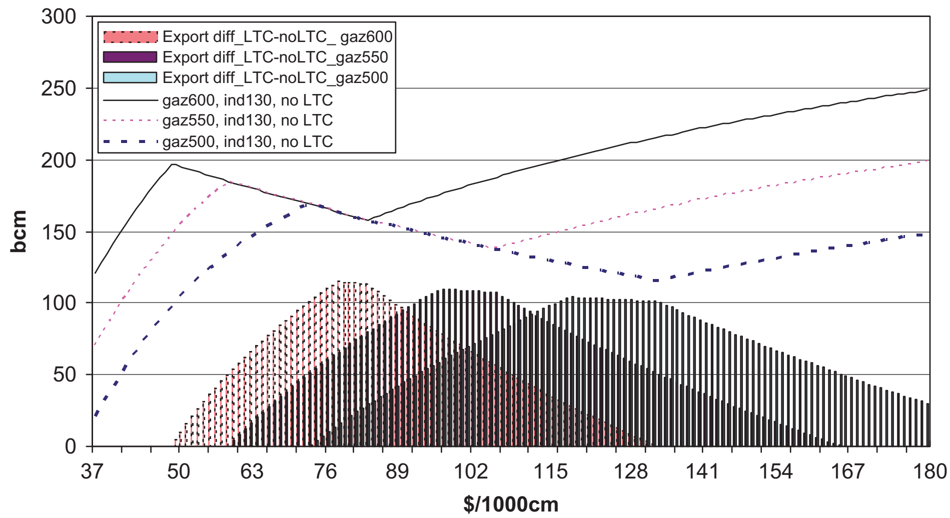

Fig. 4. Russian exports to Europe in a LTC vs. non-LTC market place.

Furthermore, several significant factors outside the control of the EU may influence Russian exports. A combination of low Russian gas prices and low production capacity may be disastrous for the future flow of Russian gas. However, for a certain range of higher Russian prices, export may partly suffer due to a gradually more profitable Russian gas market. Thus, for the EU it can be particularly important that Russia is able to further increase domestic prices toward international market levels and thereby release large gas volumes for exports. Besides price increases, the EU should also put higher pressure on Russia in terms of opening up their gas market (pipeline access) for the independent producers to encourage development and production from Russia's vast gas reserves and associated gas.

Finally, the outcome of this paper strongly signals the importance of diversification of supply for the European consumers. Particularly is this the case if the LTC market structure is fully or partly abandoned. Even though the worst-case scenario in this paper seems less likely to happen, we have not even considered other potential market shocks such as supply interruptions of Russian gas due to a number of possible reasons (conflicts with transit countries, political turmoil, terrorism, etc.).

5.4. *Sensitivity of changing elasticities in GAZALMOD and the importance of CIS*

A change in the elasticities applied in the model will not alter the primary qualitative results; that is, domestic prices will have a systematic impact on the allocation of Gazprom gas sales between domestic and export markets. However, we would expect changes in the absolute values of Gazprom supplies to the consumer markets. The model sensitivity to changes in elasticities will primarily relate to a shift of the threshold prices that determine the model phases described earlier, and the corresponding export level. Table 3 summarises the relative change in threshold prices, P_D^{T1}, P_D^{T2} and the corresponding change in export volumes, when each elasticity parameter in the model is increased and reduced alternately, keeping all other parameters at their base levels. We use the medium capacity scenario[9] for all sensitivities and model our base case LTC environment in Europe.

The results of the sensitivities show that changes in the price- and income elasticities may have considerable quantitative effects on the model output. Particularly the price- and income elasticity in Russia seems to be of significant importance. That is, if the price elasticity of Russian gas demand is reduced to -0.1, domestic prices almost move towards European net-back levels before Gazprom considers the domestic market to be more profitable than exports, referring to P_D^{T1}. In fact, in this sensitivity case we will never reach the threshold price P_D^{T2} within our modelled price range for the Russian market. Consequently, as the Russian market consumes relatively more gas for the same price level, the export level will be continuously lower than in a higher elasticity case, contributing even more to the risk of Russian exports being close to or lower than existing contracts. If the price elasticity in Russia increases to $-0{,}5$, the threshold price P_D^{T1} will shift to the left in our figures and export levels will be higher than in our reference elasticity case for the same price level. However, now P_D^{T2} will also shift to the left and exports will for that price level be *lower* than exports with our reference elasticity.

Even though the elasticities applied in the model have a significant impact on the model results, we can not in any case dismiss the fact that both the Russian gas price level and the production capacities of Russian gas producers are highly important for the flow of future Russian gas exports to Europe. As we are prone to believe that Russian elasticities are probably lower rather than higher than our

[9]Gazprom production capacity (gaz) = 550 bcm, independent production capacity (ind) = 130 bcm.

Table 3
Effects of elasticity changes on P_D^{T1}, P_D^{T2} and Gazprom's export (in %)

	Demand price elasticity in Russia		Demand price elasticity in Europe		Demand income elasticity in Russia		Demand income elasticity in Europe	
Elasticity used in the model	−0.3		−0.5		0.7		0.7	
New elasticity	−0.1	−0.5	−0.3	−0.7	0.5	0.9	0.5	0.9
Change in P_D^{T1} (%)	60	−23	−17	12	−22	18	−9	12
Change in export at P_D^{T1} (%)	−22	10	−10	8	10	−7	−5	6
Change in P_D^{T2} (%)	–	−27	−4	3	−15	16	−9	10
Change in export at P_D^{T2} (%)	–	−23	−3	2	10	−10	−6	6

reference case, this further strengthens the possibilities of future Russian exports not being as large as the EU seems to expect.

In this study we assume a priori that supply and demand within the CIS states are identical. If Gazprom maintains its control over central Asian gas production and transportation, an optimistic production pattern in these countries may help Gazprom with solving its overall delivery problems when capacities and/or domestic prices are low. On the other side, a pessimistic production pattern in central Asia will most likely worsen Gazprom's problems, as more gas is needed to carry out potential delivery commitments to its neighbouring CIS countries. A second way out for Gazprom is to buy independent companies or their respective gas resources, a pattern that we actually observe today. However, this may not change our model results significantly, as we may well interpret a combination of high Gazprom capacities and low independent capacities as such a scenario.

6. Conclusions

In the light of the EU's concern about the too high market share of Russian gas in Europe, the aim of this study has been to stress the possible effect on Russian gas exports from different future Russian gas prices levels. Given a plausible range of Russian domestic gas prices in 2015, we have run scenarios based on fundamental uncertainties related to Gazprom and non-Gazprom production capacities. We have also investigated how liberalising the European gas market towards entirely gas-to-gas competition may affect Russian export decisions. With respect to the European security of supply issue, our results point out that all these factors should be considered carefully when predicting future Russian exports to Europe.

Even though the quantitative model results are exposed to various fundamental uncertainties, the importance of not neglecting the Russian price reform and overall Russian production capacities when predicting future Russian gas exports should not be undervalued. Firstly, it seems clear that increased domestic gas prices in Russia from today's levels will create improved export possibilities due to decreasing Russian gas demand and increased supplies from independent producers. In fact, a Russian gas market price reform may be absolutely necessary if Russian export targets and even export commitments through LTCs are to be achieved. Still, if Gazprom continues to be the domestic gas provider of last resort, scarce production capacities of both Gazprom and independent producers will restrict export volumes if the domestic market is given political priorities. Secondly, our results indicate that if domestic prices become sufficiently high, the domestic market becomes the most profitable market at the margin. This will again lead to relatively lower Russian gas exports as Gazprom will allocate gas from the now less profitable export market. Only when Russian gas prices are so high that Gazprom alone can cover the domestic market, export volumes may again increase for even higher domestic prices.

Finally, our simulations of a gas market without LTCs indicate that a European gas market approaching liberalisation may provide even less Russian exports in the future. If Gazprom is no longer constrained by contract commitments it may be optimal to reduce exports when aiming for a balance between marginal revenues in both domestic and export markets. The ranges of Russian exports due to production capacities, Russian price policies as well as the European market structure, suggest that a good policy recommendation for the EU countries would be to diversify its imports. Then the vulnerability of one source (e.g. Russia) is less and the competition at the European market is hopefully increased.

Acknowledgements

We are grateful to comments and suggestions from Knut Einar Rosendahl, Mads Greaker, Olav Bjerkholt and Ådne Cappelen. Funding from the Nordic Council of Ministers and The Norwegian Research council is also acknowledged.

Appendix A

Here we discuss the FOC's of Gazprom's allocation problem (1)–(4) in Section 2 of the paper, and formally prove how Gazprom's gas supplies changes as the domestic price, P_D, increases.

Subject to (1)–(4), the following Lagrangian may be formulated:

$$\begin{aligned} L(Q_D, Q_E) = {} & P_D Q_D + P_C Q_C + P_E(Q_E + \sum Q_i)Q_E \\ & - C_G(Q_D + Q_C + Q_E) - w(Q_E + Q_C) \\ & - \lambda(Q_D + Q_E + Q_C - K) - \gamma(D(P_D) \\ & - S_I(P_D, M) - Q_D) - \varphi(Q_D - D(P_D)). \end{aligned} \quad \text{(A.1)}$$

Then, the following straightforward first-order Kuhn-Tucker conditions (FOC) yield:

$$\text{FOC}: \quad \text{w.r.t. } Q_D: \quad P_D - C'_G - \lambda + \gamma - \varphi = 0, \quad \text{(A.2)}$$

$$\begin{aligned} &\text{FOC}: \quad \text{w.r.t. } Q_E: \quad MR(Q_E) - C'_G - w - \lambda = 0 \\ &Q_D, \; Q_E > 0. \end{aligned} \quad \text{(A.3)}$$

In (A.3), the export marginal revenue can be expressed as

$$MR(Q_E) = P'_E(Q_E + \sum Q_i(Q_E))Q_E + P_E(Q_E + \sum Q_i(Q_E)). \quad \text{(A.4)}$$

$\sum Q_i(Q_E)$ in (A.4) reflects that in the Cournot equilibrium, for any given Russian export to the spot market, Q_E, there is a unique supply from non-Russian producers to the spot market. In the FOC expressions above, Gazprom's production capacity constraint, the delivery obligation to the domestic market and the restriction of Gazprom's supply to domestic consumers created by the domestic demand, are introduced with the non-negative shadow prices (Lagrange multipliers) λ, γ and φ, respectively. Hence, shadow price λ represents the valuation of an additional available capacity unit, shadow price γ represents the valuation of the reduction of delivery obligations to the domestic market by one unit and shadow price φ reflects the value of an additional unit natural gas demanded by Russian consumers. When a shadow price is non-zero, the respective constraint is binding.

If $\gamma = 0$ and $\varphi = 0$, both Gazprom's obligation to cover the domestic demand, (3), and the demand constraint (4) are non-binding. Then from the FOCs we get

$$MR(Q_E) - w = P_D. \quad \text{(A.5)}$$

Eq. (A.5) says that Gazprom allocates its gas production between two markets, balancing the marginal revenues between domestic and export markets. Thus, differentiating the FOCs with respect to P_D we get

$$\frac{\partial Q_E(P_D)}{\partial P_D} = \frac{1}{MR'(Q_E)} \leqslant 0, \quad \text{(A.6)}$$

$$\frac{\partial Q_D(P_D)}{\partial P_D} = \frac{1}{C''_G} \geqslant 0. \quad \text{(A.7)}$$

In this case, a positive λ will equally raise the cost of supply to both markets, and hence, downsize the supply of both Q_D and Q_E.

If $\gamma > 0$ and $\varphi = 0$, constraint (3) in Gazprom's allocation problem is binding, and Gazprom will supply more to the domestic market than what is optimal for the company.

Given $Q_D = D(P_D)$-$S_I(P_D,M)$, where Q_D is a decreasing function of P_D, we get

$$\frac{\partial Q_D(P_D)}{\partial P_D} = \frac{\partial D(P_D)}{\partial P_D} - \frac{\partial S(P_D, M)}{\partial P_D} \leqslant 0. \quad \text{(A.8)}$$

In order to reduce the costs at the domestic market and to reduce domestic deliveries, Gazprom may allow as much gas as possible from the independent producers to the domestic market, hence; $Q_I = S_I(P_D,M)$ and $(\partial Q_I/\partial P_D) \geqslant 0$. Consequently, Gazprom's domestic supply is residual after the optimal supply of the independent producers.

If $\gamma = 0$ and $\varphi > 0$, then constraint (4) in the Gazprom's allocation problem is binding, otherwise Gazprom would supply to the domestic market more than what is demanded. Thus, Gazprom alone will cover the domestic demand; $Q_D = D(P_D)$ and $Q_I = 0$, $(\partial Q_D/\partial P_D) \geqslant 0$.

Finally, for both cases $\gamma > 0$, $\varphi = 0$ as well as $\gamma = 0$, $\varphi > 0$, Q_E is determined only by (A.3), while Q_D is constant under the given domestic price, P_D, Differentiating (A.3) with respect to P_D we get

$$\frac{\partial Q_E}{\partial P_D} = \frac{C''_G(\partial Q_D/\partial P_D)}{MR'(Q_E) - C''_G} \geqslant 0. \quad \text{(A.9)}$$

When $\lambda \geqslant 0$ in (A.3), that is the production capacity constraint (2) is binding, we have that export supplies at the European spot market is residual after domestic and long-term export supplies

$$Q_E = K - Q_D - Q_C. \quad \text{(A.10)}$$

References

Al-Sahlawi, M.A., 1989. The demand for natural gas: a survey of price and income elasticities. The Energy Journal 10 (1), 77–90.

Bjerkholt, O., Gjelsvik, E., Olsen, Ø., 1990. The western European gas market: deregulation and supply competition. In: Bjerkholt, O., Olsen, Ø., Vislie, J. (Eds.), Recent Modelling Approaches in Applied Energy Economics. Chapman & Hall Ltd., London, pp. 3–28.

BP, 2006. BP Statistical Review of World Energy, June 2006.

EC, 2000. Towards a European strategy for the security of energy supply. The European Commission Green Paper, at 〈http://europa.eu.int/eur-lex/en/com/gpr/2000/act769en01/com2000_0769en01-01.pdf〉.

EC, 2006. A European strategy for sustainable, competitive and secure energy.

EIA, 2006. International Energy Outlook 2006, Energy Information Administration, June 2006, Washington.

Fellers, G., 2004. Increased competition, declining resource base challenge Gazprom. Pipeline & Gas Journal, 45–47.

Finon, D., Locatelli, C., 2002. The Liberalisation of the European Gas Market and its Consequences for Russia. Russian Institute of Energy Policy and Economics, Grenoble, France.

Gazprom, 2004. Financial Report 2004, at 〈www.gazprom.ru〉.

Golombek, R., Gjelsvik, E., Rosendahl, K.E., 1995. Effects of liberalising the natural gas markets in Western Europe. The Energy Journal 16 (1), 85–111.

Holtsmark, B., Mæstad, O., 2002. Emission trading under the Kyoto Protocol—effects on fossil fuel markets under alternative regimes. Energy Policy 30, 207–218.

IEA, 1993. Russian Energy Prices, Taxes and Costs. International Energy Agency, Paris.

IEA, 2002. Russian Energy Survey 2002. International Energy Agency, Paris.

IMF, 2006. World Economic Outlook Database, September 2006, at ⟨www.imf.org⟩.

Landes, A., Smith, R., Savchik, E., 2004. Gazprom: Don't Miss It!. Renaissance Capital, Moscow (April).

Neumann, A., von Hirschhausen, C., 2004. Less long-term gas to Europe? A quantitative analysis of European long-term gas supply contracts. Zeitschrift fur Energiewirtschaft 28 (3), 175–182.

Oil & Gas Journal, 2001. Central Asian gas crucial to future Russian gas supply. Oil & Gas Journal (August 13, 2001).

Oil & Gas Journal, 2005. Russia, Turkmenistan end gas-price standoff. Oil & Gas Journal (May 2, 2005).

OME, 2004. The role and future prospects of natural gas in the Mediterranean Region. Obsevatoire Mediterraneen de L'Energie.

Oostvoorn, F.v., Askounis, D., Aslanian, G., Makarov, A., Velthuijsen, J.W., 1999. Russian energy markets: current situation and opportunities for co-operation. ECN Report No. 99-027, February 1999.

Petroleum Economist, 2002. Nice reserves—shame about the location, Petroleum Economist, September 2002, p. 16.

Quast, O., Locatelli, C., 1997. Russian natural gas policy and its possible effects on European gas markets. Energy Policy 25 (2), 125–133.

Rosstat, 2006. Russia in Figures 2005. Statistical Handbook. Federal State Statistics Service (Rosstat), Moscow.

Russia's Energy Strategy through 2020, 2003. A publication from government of the Russian Federation.

Solodnikova, K., 2003. Estimation of energy demand elasticities in Russia. Master Thesis, New Economic School, Moscow.

Spanjer, A.R., 2006. Russia and Europe's mutual dependency: consequences for Russian gas price reform and European security of supply. Papers and Proceedings of the Seminar Infrastructure Reliability, TU Delft, The Netherlands, June 22, 2006.

Stern, J.P., 1995. The Russian Natural Gas "Bubble"; Consequences for European Gas Markets. The Royal Institute of International Affairs, London.

Stern, J.P., 2005. The Future of Russian Gas and Gazprom. Oxford University Press for the Oxford Institute for Energy Studies.

Tarr, D., Thomson, P., 2004. The merits of dual pricing of Russian natural gas. The World Economy 27 (8), 1173–1194.

von Hirschhausen, C., Meinhart, B., Pavel, F., 2005. Transporting Russian gas to Western Europe: a simulation analysis. The Energy Journal 26 (2), 49–68.

WGI, 2005a. Lukoil Looks to Gas for Growth. World Gas Intelligence (June 1, 2005, pp. 4–5).

WGI, 2005b. Why Everybody Likes Novatek. World Gas Intelligence (March 23, 2005, pp. 2–3).

WGI, 2005c. New Gazprom Vision. World Gas Intelligence (June 29, 2005, pp. 1–2).

WGI, 2006a. Gazprom, Ukraine Questions. World Gas Intelligence (January 11, 2006, pp. 1–2).

WGI, 2006b. Gazprom Accepts Turkmen Gas Price. World Gas Intelligence (September 6, 2006, p. 5).

WGI, 2006c. Market Insight: Wild Times in Europe. World Gas Intelligence (January 25, 2006, p. 6).