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The strategic implications of the second Russia-China gas deal on the European gas market: insights from a Hotelling model in a game theoretical framework

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Abstract

At the end of 2014, Russia and China signed a framework for the second gas agreement. According to this agreement, Russia will supply 30 billion cubic meters (bcm) of gas to China over 30 years via the future Altai pipeline, which would connect Asian and European gas markets. This paper analyses the potential impacts of the second gas agreement on the European gas market. The analysis is based on an analytical and numerical Hotelling model. The core Hotelling model has been modified as follows: (i) three gas markets (Europe, China, and Russia) are considered; (ii) Russia is assumed to have market power in the European and Chinese gas markets; (iii) domestic gas prices are regulated in Russia; (iv) a finite planning horizon, which implies that agents plan for a finite future, is incorporated; and (v) a stock effect, which occurs when the marginal production cost is affected by the remaining stock, is introduced. In the numerical Hotelling model, the European gas market is depicted as oligopolistic competition in a game theoretical framework. The numerical Hotelling model is formulated as a mixed complementarity problem. The analysis leads to several interesting findings. Export netback gas prices for Europe and China should not necessarily be the same due to different degrees of market power, even if the resource constraint is binding. Gas exports to China will not necessarily result in re-optimisation of the Russian profit maximisation strategy in Europe, at least in the medium-term. Given the assumptions of a finite planning horizon and large gas reserves, Russia could face a non-binding resource constraint. In that case, Russia will continue to supply gas to Europe. Nevertheless, gas exports to China ultimately reduce the potential of Russia to supply gas to Europe in the long-term. Our results show that Russia could take a stronger bargaining position after 2050, when scarcity concerns could become more pronounced. Furthermore, in the presence of a stock effect, Russia could bargain with Europe for a higher gas price to compensate for an increase in the marginal production cost. Under a supply elasticity equalling unity, the stock effect could result in an annual reduction in the export supply of gas to Europe by 12 bcm. Nevertheless, scarcity concerns as well as adverse stock effects could be diminished if implicit subsidies on domestic gas consumption are reduced in Russia. The domestic gas market covers a large potential for gas exports. A 20% increase in the domestic gas price in Russia could potentially release 29 bcm of gas for export markets annually.

Key words: gas deal, Russia, Europe, China, resource constraint, Hotelling model, game theory, bargaining, Cournot oligopoly, finite planning horizon

Content

1. Introduction

In May of 2014, Russia and China signed a $400 billion gas contract. According to this contract, Russia will supply 38 billion cubic meters (bcm) of gas annually over 30 years, beginning in 2018, via the so-called “eastern route” (the Power of Siberia pipeline), from Kovykta to Khabarovsk and then to Vladivostok (Reuters, 2014). Gas will be supplied from remote East Siberian gas reserves, which will unlikely be economically rational for the European gas market (OECD/IEA, 2014).

A few months later, Russia and China signed a framework for a second gas agreement. According to this second gas agreement, Russia will supply 30 bcm annually over 30 years via the so-called “western route” (the Altai pipeline) (RT, 2014). The gas price has not yet been decided. The second gas deal is based on commercial and geopolitical rationales for Russia and China (Henderson, 2014). In contrast to the first gas agreement, building the Alai pipeline would enable Asian and European gas markets to connect.

Both sides are expected to benefit from both gas agreements. For Russia, exporting gas to China is an opportunity to diversify its gas supplies. This becomes especially important for Russia due to the unstable situation in Ukraine[1]. Furthermore, both gas agreements could result in a substantial profit for Russia, depending on the gas price. For China, gas exports from Russia enable a reduction in local air pollution and greenhouse gas (GHG) emissions, by switching away from coal towards gas. Gas imports from Russia also allow China to diversity its gas imports.

Furthermore, third parties (e.g., European and Asian consumers and producers of gas) may be indirectly affected. Europe has been the main export gas market for Russia. Gas exported to China according to the second gas agreement could have supplied European economies. Therefore, increases in the export supply of gas to China may lead to lower gas exports to Europe. This paper focuses on possible impacts from the second gas agreement on the European gas market.

[1] The main amount of Russian gas towards European countries transits via Ukraine.

Although the media has given a lot of attention to this issue, there has not yet been a conceptual economic analysis that relies on theory. This paper aims to shed light on this politically important issue. The objective of this paper is to analyse the implications of the second Russia-China gas agreement on the European gas market. The analysis is based on an analytical and numerical Hotelling model, which has been modified as follows: (i) three gas markets (Europe, China, and Russia) are considered; (ii) Russia is assumed to have market power in the European and Chinese gas markets; (iii) domestic gas prices are regulated in Russia; (iv) a finite planning horizon, which implies that agents plan for a finite future, is incorporated; and (v) a stock effect, which occurs when the marginal production cost is affected by the remaining stock, is introduced. In the numerical model, the European gas market is modelled as oligopolistic competition in a game theoretical framework. The numerical Hotelling model is formulated as a Mixed Complementarity Problem (MCP).

The rest of the paper is organised as follows: Section 2 provides a brief description of the Russian gas sector; Sections 3 and 4 describe the Chinese and European gas markets, respectively; Section 5 presents the methods; Section 6 presents and discusses the results from the analytical and numerical models; and Section 7 provides conclusions.

2. The Russian Gas Sector

Russia has the largest proved reserves of natural gas in the world (BP, 2014). Moreover, Russia is one of the world's largest producers and exporters of natural gas (EIA, 2014). Paltsev (2014) analysed different scenarios for Russia's natural gas exports to 2050. He found that over 20-40 years Russia has sufficient gas reserves and capacity to supply both the European and Asian gas markets. Furthermore, over the last several decades, there has been even oversupply of gas in the domestic gas market since non-Gazprom producers have expanded their production and capacity (Henderson, 2012; Henderson, 2014).

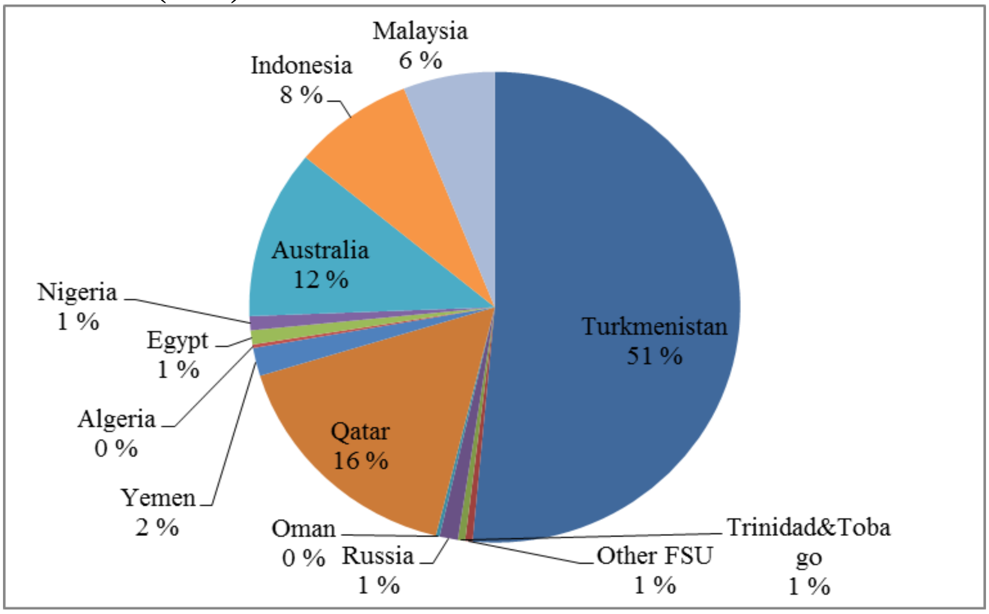
The largest domestic producer of natural gas in Russia is Gazprom, whose share accounted for 71.3% of total gas production in 2013 (Ministry of Energy, 2014). Open joint stock company Gazprom is a state run company with a government ownership share of slightly above 50%. Gazprom operates as a vertically integrated company that operates production, distribution and transmission of natural gas (Gazprom, 2014a). Gazprom is a proprietary organisation in Russia's unified system of gas transmission and therefore has control over all domestic and export transmission of natural gas from Russia (Gazprom, 2014c). Nevertheless, Gazprom does not have absolute control over production of natural gas in Russia. The role of independent gas producers has increased recently, with their production share accounting for 28.7% of total gas production in 2013 (Ministry of Energy, 2014).

Three main gas markets are distinguished: (1) the domestic market, (2) the European market, and (3) the Commonwealth of Independent States (CIS's) market. Russia is not only a large producer of gas, but it is also a large gas consumer. The domestic market is the largest market, whose share accounted for 49.4% of total gas supply in 2013 (Gazprom, 2014b). It should be noted that domestic gas prices are regulated in Russia and are substantially lower than exports netback prices; for example, domestic gas prices were approximately 30% of the export netback price for Western Europe in 2012 (Gazprom, 2014b). Russia is one of the world's largest exporters of natural gas: for example, its export share of gas by pipeline was 30% of the world's pipeline export of natural gas production in 2013 (BP, 2014). According to *Federal Law No.117 from July 18, 2006,* (the Russian Government, 2006) among Russian gas producers, only Gazprom is entitled to export natural gas, which means that in addition to its pipeline monopoly Gazprom also has a legal monopoly with respect to natural gas exports. On export markets, Gazprom operates under long-term contracts, which usually last for 25 years (Gazprom, 2014c). Gazprom exports natural gas to 32 countries such as CIS, EU as well as Turkey, Japan and other Asian countries (Gazprom, 2012). The largest importers of Russian natural gas are Ukraine and Germany. The consumption share of Russian gas in most European markets is high. Therefore, Russia can have some market power in these markets. For example, natural gas consumption in countries such as Slovakia, Finland, and Belarus consists mainly of gas deliveries from Russia (BP, 2014).

3. The Chinese Gas Market

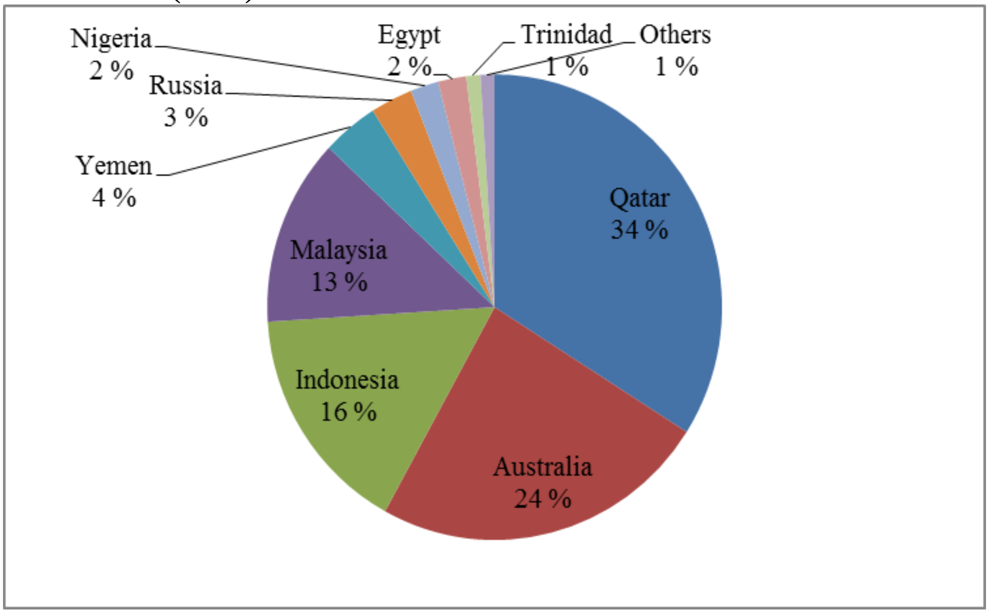
China itself is a large gas producer and it has large indigenous reserves of conventional and unconventional gas (Henderson, 2011). In 2007, China became a net gas importer (EIA, 2014). In 2012, the import share of gas was 28% of total gas consumption in China (EIA, 2014). The main import source for gas in China is Turkmenistan, which accounted for half of total gas import in 2012, followed by Qatar (16%), and Australia (12%) (Fig. 1). The import share of gas from Russia is quite small, yet the gas agreement could be an opportunity for Gazprom to increase its share in the Asian growing gas market.

Fig. 1: Imports of gas to China in 2012.
Source: BP (2013)



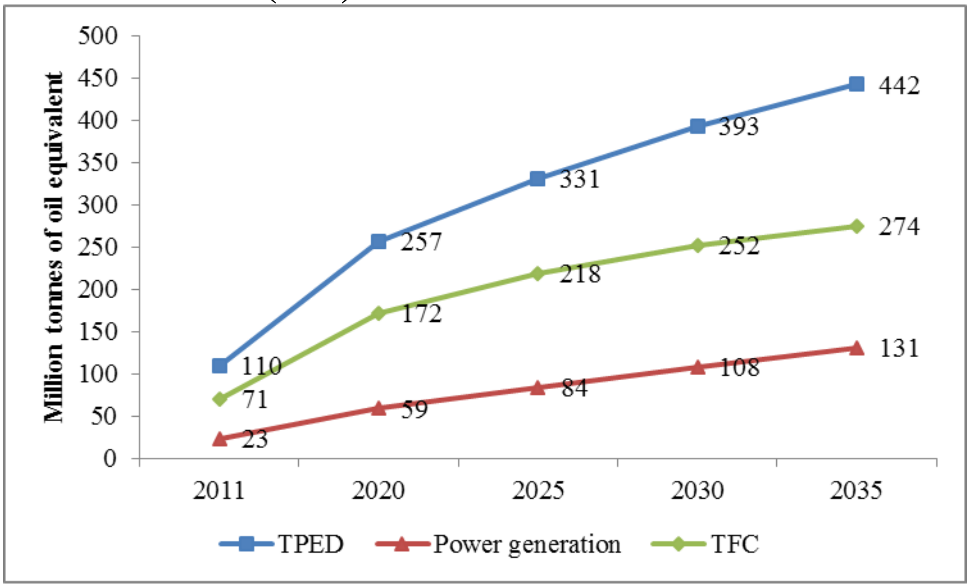
China imports liquefied natural gas (LNG) as well as piped gas. The main supplier of piped gas is Turkmenistan. In 2012, China imported 41.4 bcm of gas, where almost half of that (21.4 bcm) was piped gas and the rest was LNG (BP, 2013). The import of LNG in 2012 came mainly from Qatar (34%), followed by Australia (24%) and Indonesia (16%) (Fig. 2). The share of Russian LNG was rather moderate (3%).

Fig. 2: Imports of LNG to China in 2012.
Source: EIA (2014)



The demand for gas in China is expected to increase (Fig. 3). According to the *New Policies Scenarios* of World Energy Outlook (OECD/IEA, 2013), the average annual growth of total gas demand accounts for 6% from 2011 until 2035. The share of gas in total primary energy demand (TPED) as well as total final consumption (TFC) is expected to increase from 4% to 11%. Growing gas demand results from economic growth and it is also in part politically driven because China aims to reduce the usage of coal. China announced a peak of its GHG emissions around 2030 (CNN, 2014). This goal should be achieved by a replacement of coal with gas, nuclear, and renewables.

Fig. 3: Projections of gas consumption in China until 2035.
Source: OECD/IEA (2013)



According to CEIC (Chen, 2014), the main domestic gas consumer in China in 2012 was industry with a share of 49% of total consumption, followed by the residential sector (20%), transport (10%), power generation sector (16%), and others (5%).[2] Chemicals and petrochemicals industries (e.g., fertilizer production) are the most gas-intensive sectors in China (Higashi, 2009). There are large differences in endowment and consumption of gas among regions; for example, both the coastal and central regions cover approximately 60% of total gas consumption, whereas the western region is responsible for 60% of total indigenous gas production in China (Chen, 2014).

Domestic gas prices are regulated in China and are lower than import gas prices. Artificially low gas prices can be considered as implicit subsidies for domestic consumers. Over the last few years, China undertook some steps for a more dynamic and efficient gas price system. Currently, China has implemented tiered gas pricing, with two city-gate price ceilings. One ceiling is applied for incremental gas and another one for existing gas. The city-gate price for existing gas is planned to be gradually increased. In 2013, the price ceiling for incremental gas was approximately by 40% higher than that for existing gas on average (Chen, 2014).[3]

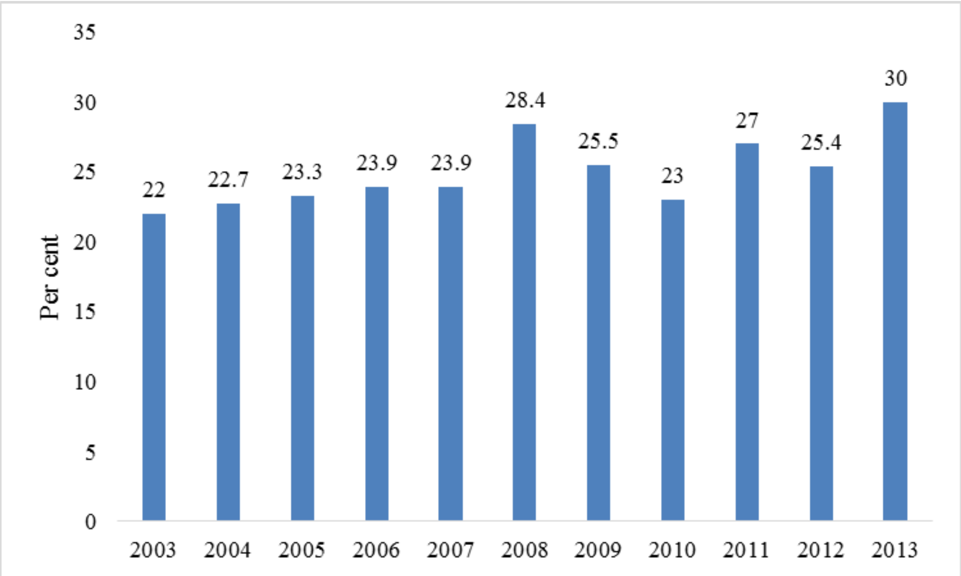
[2] The shares are approximated.
[3] Incremental gas is the volume of gas that excesses that registered in 2012.

Currently, there are huge differences in gas prices among Chinese regions. This is due to distribution of gas deposits, accessibility to transport routes. The most gas abundant western region that also is closer to piped gas imports has the lowest gas prices compared to the coastal and central regions. For example, the gas price for residential consumers in some provinces of the coastal region is three times higher than that in the western region (Chen, 2014). It should be noted that the difference in gas prices within the regions are also substantial.

4. The European Gas Market

Russia is one of the largest exporters of gas to Europe, followed by Norway, Algeria, and Qatar (EC, 2014). Hence, Russia plays an import role in the European gas balance. Fig. 4 shows the market share of Gazprom in total imports of gas in Western Europe from 2003 until 2013.

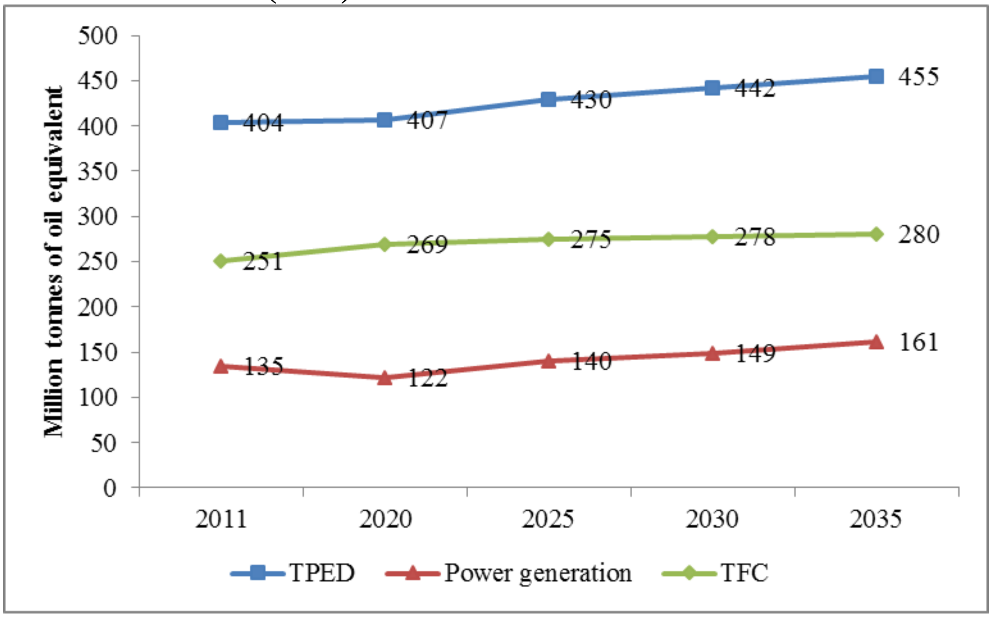
Fig. 4: The market shares of Gazprom in total gas imports of Western Europe.
Source: Gazprom (2014c)



The largest importers of Russian gas in the EU are Germany, Italy, and Poland (Table 1). Turkey is also a large importer of Russian gas. The import shares of Russian gas in total gas supplies of many European countries are substantial; for example, total gas supply in some European countries such as Bulgaria, Finland, Latvia, Lithuania, and Slovakia consists mainly of imports from Russia.

Increases in gas demand in European economies are less promising that those in China. According to the *New Policies Scenarios* of World Energy Outlook (OECD/IEA, 2013), the average annual growth of total gas consumption in the EU is approximately 0.5% from 2011 to 2035 (Fig. 5). Furthermore, Russian exports of gas to the EU have been decreased since 2008 due to economic crisis, exports of LNG from USA and more support for renewable energy in the EU (Henderson, 2014).

Fig. 5: Projections of gas consumption in the EU until 2035.
Source: OECD/IEA (2013)



5. Methods

5.1 Analytical model

Europe is the largest export market of gas for Russia. We start our analysis with an analytical dynamic partial equilibrium model for the gas market. It is known that markets of exhaustible resources operate in a different manner than markets of ordinary goods because resource scarcity influences production decisions. A Hotelling model is a widely used method to analyse markets of exhaustible resources such as gas and oil. Our analysis is also based on a Hotelling model. According to the "standard" Hotelling model, the extraction should decrease and the price should increase over time. Nevertheless, empirical evidence shows the opposite. This means that results from a standard Hotelling model may be misleading. Therefore, for the analysis purpose, we modify the original Hotelling model as follows. First, in our Hotelling model we consider many supply options; there is a single gas producer (Russia), which decides on supplying gas to the domestic market and two export markets (Europe and China). The European gas market in that model represents EU and CIS countries, which are the main importers of Russian gas. Second, it is assumed that Russia has market power in the export markets (i.e., imperfect competition). Third, domestic gas prices in Russia are assumed to be regulated. Further, following Spiro (2013), we implement a rolling planning horizon (i.e., finite planning horizon). A rolling planning horizon implies that agents plan for a finite future with regularly revising the plan (Spiro, 2013). Infinite time horizon is rather an unrealistic assumption, which was often criticised. The standard Hotelling model underlies the assumption of perfect information. In reality, development of future demand and prices for gas as well as production costs is very uncertain. Spiro (2013) analytically showed that the assumption of a large stock of resources and a rolling planning horizon could relax the scarcity consideration. In other words, the resource constraint becomes non-binding.[4] As a result, extraction of exhaustible resources may deviate from the Hotelling path. Indeed, as we discussed in the previous section Russia has large gas reserves, which could be sufficient to satisfy demand for gas in Europe and China (Paltsev, 2014). Fifth, following Lin et al. (2008) we incorporate a stock effect, which depicts the relationship between marginal production cost and the remaining stock. This analytical framework enables to analyse the interaction between market power and resource constraints, and how these factors may affect the bargaining strategy of Russia in the European gas market. The model is as follows.

$$max \sum_{t=0}^{T} (1+r)^{-r} * \begin{pmatrix} \big(P1(t) * E1(t) - C1(t)\big) + \big(P2(t) * E2(t) - C2(t)\big) \\ +\big(pd * D(t) - CD(t)\big) \end{pmatrix}$$

s.t. $S(0) \geq \sum_{t=0}^{T} E1(t) + \sum_{t=0}^{T} E2(t) + \sum_{t=0}^{T} D(t)$

where

$E1(t)$ is the supply of gas to Europe

$E1(t)$ is the supply of gas to China

$D(t) \equiv D(pd(t), t)$ is the domestic demand for gas in Russia

$P1(t)$ is the export netback price of gas to Europe

[4] It should be noted that in comparison to Spiro's model, we consider many markets, imperfect competition, and a stock effect.

$P2(t)$ is the export netback price of gas to China

$pd(t)$ is the domestic gas price in Russia

$P1(t) \equiv P1(E1(t), t)$ is the inverse demand function for gas in Europe

$P2(t) \equiv P2(E2(t), t)$ is the inverse demand function for gas in China

$C1(t) \equiv C1(E1(t), S, t)$ is the production cost function for supplying gas to Europe

$C2(t) \equiv C2(E2(t), S, A, t)$ is the production cost function for supplying gas to China

$CD(t) \equiv CD(D(t), S, t)$ is the production cost function for supplying gas to Russia

A is a parameter for technological efficiency improvement

$S(t)$ is the resource stock

The properties of implicit functions are described in Appendix A, Supplementary data.

Russian gas producers are assumed to maximise the net present value of profit arising from the gas markets subject to an intertemporal resource constraint. We define a Lagrangian function to solve this dynamic optimization problem:

$$L(E1, E2, D, \lambda) = \sum_{t=0}^{T}(1+r)^{-t} * \Big(\big(P1(t) * E1(t) - C1(t)\big) + \big(P2(t) * E2(t) - C2(t)\big) + \big(pd(t) * D(t) - CD(t)\big)\Big) + PR * (S(0) - \sum_{t=0}^{T} E1(t) - \sum_{t=0}^{T} E2(t) - \sum_{t=0}^{T} D(t))$$

where *E1*, *E2* and *D* are the control variables

S is the state variable

PR is the co-state variable.

This is a constrained optimisation problem. The objective function of maximisation problem is concave and the associated constraint is convex, which means that Karush-Kuhn-Tucker conditions are both necessary and sufficient for a global optimal solution (i.e., unique solution).

Differentiating the Lagrangian with respect to *E1*, *E2*, *D*, and *PR* we obtain the following Karush-Kuhn-Tucker conditions:

$$P1(t) + E1(t) * P1_{E1}(t) - C1_{E1}(t) \leq PR(t) + C1_s(t) \quad \perp \quad E1(t) \geq 0 \qquad \text{(A1)}$$

$$P2(t) + E2(t) * P2_{E2}(t) - C2_{E2}(t) \leq PR(t) + C2_s(t) \quad \perp \quad E2(t) \geq 0 \qquad \text{(A2)}$$

$$pd(t) - CD_D(t) \leq PR(t) + CD_S(t) \quad \perp \quad D(t) \geq 0 \qquad \text{(A3)}$$

$$S(0) \geq \sum_{t=0}^{T} E1(t) + \sum_{t=0}^{T} E2(t) + \sum_{t=0}^{T} D(t) \qquad \perp \; PR \geq 0 \qquad \text{(A4)}$$

where

$$PR(t) = PR * (1 + r)^t$$

Eq. (A1), (A2), and (A3) are the static efficiency conditions, which ensure that the marginal profit equals zero. Eq. (4) determines the intertemporal resource constraint.

Analogously, we find the Karush-Kuhn-Tucker conditions for the period $t+1$. If the resource constraint is binding, we can combine the first order conditions for profit maximisation in both periods to obtain:

$$\frac{P1(t+1)+E1(t+1)*P1_{E1}(t+1)-C1_{E1}(t+1)-C1_{S}(t+1)}{P1(t)+E1(t)*P1_{E1}(t)-C1_{E1}(t)-C1_{S}(t)} = 1 + r$$

$$\frac{P2(t+1)+E2(t+1)*P2_{E2}(t+1)-C2_{E2}(t+1)-C2_{S}(t+1)}{P2(t)+E2(t)*P2_{E2}(t)-C2_{E2}(t)-C2_{S}(t)} = 1 + r$$

$$\frac{pd(t+1)-CD_{D}(t+1)-CD_{S}(t+1)}{pd(t)-CD_{D}(t)-CD_{S}(t)} = 1 + r$$

This is an implication of the Hotelling price rule, where the resource rent should increase over time with an interest rate. These equations determine dynamic efficiency conditions. More details on the analytical model and its solution can be found in Appendix A, Supplementary data.

5.2 Numerical model

Based on the analytical model, we build a numerical model. For the numerical model, we use explicit supply and demand functions. There are a few other differences between the analytical and numerical model. In contrast to the analytical model, in the numerical model we consider two gas producers: Russia and the Rest of the World (RoW). In the numerical Hotelling model, the European gas market is depicted as oligopolistic competition in a game theoretical framework. Therefore, strategic considerations of gas producers are taken into account. The export supply from the RoW is endogenously determined in the numerical model to depict a more realistic price response. We assume that Russia and the RoW exercise market power in the European gas market by playing a Cournot non-cooperative game with a Nash equilibrium. Therefore, the numerical Hotelling model can be characterised as a game theoretical model. Another difference between the models is that in the numerical model the export supply of gas from Russia to China is an exogenous variable, which we increase to simulate the second gas deal.[5] The model is as follows:[6]

$$P1(t) * \left(1 - \frac{SH1(t)}{ede}\right) = MC(t) + PR * (1+r)^t \qquad \perp E1(t) \qquad \text{(N1)}$$

$$P1(t) * \left(1 - \frac{SHR(t)}{ede}\right) = mcr(t) \qquad \perp ER(t) \qquad \text{(N2)}$$

$$MC(t) = admc(t) * \left(E1(t) + e2(t) + D(t)\right)^{es} \qquad \perp MC(t) \qquad \text{(N3)}$$

$$SH1(t) = \frac{E1(t)}{ET(t)} \qquad \perp SH1(t) \qquad \text{(N4)}$$

$$SHR(t) = \frac{ER(t)}{ET(t)} \qquad \perp SHR(t) \qquad \text{(N5)}$$

$$ET(t) = E1(t) + n * ER(t) \qquad \perp P1(t) \qquad \text{(N6)}$$

$$ET(t) = adet(t) * P1(t)^{ede} \qquad \perp ET(t) \qquad \text{(N7)}$$

$$D(t) = add(t) * pd(t)^{edd} \qquad \perp D(t) \qquad \text{(N8)}$$

$$s = \sum_{t=0}^{T} E1(t) + \sum_{t=0}^{T} e2(t) + \sum_{t=0}^{T} D(t) \qquad \perp PR \qquad \text{(N9)}$$

where

$P1(t)$ is the export netback price of gas to Europe

PR is the resource price

$pd(t)$ is the domestic gas price in Russia

$SH1(t)$ is the market share of Russian gas in the European gas market

$SHR(t)$ is the market share of RoW gas in the European gas market

ede is the price elasticity of demand in the European gas market

edd is the price elasticity of demand in the Russian gas market

es is the elasticity of a stock effect (the supply elasticity)

$MC(t)$ is the marginal production cost of Russia

$mcr(t)$ is the marginal production cost of the RoW

$admc(t)$ is the shift parameter for the marginal cost function

$adet(t)$ is the shift parameter for the import demand function in Europe

$add(t)$ is the shift parameter for the domestic demand function in Russia

[5] It should be noted that these differences between the analytical and numerical model do not change general conclusions.

[6] Exogenous variables are noted in small letters, whereas endogenous variables in capitals.

$E1(t)$ is the export supply of gas from Russia to Europe

$e2(t)$ is the export supply of gas from Russia to China

$D(t)$ is the domestic demand for gas in Russia

$ER(t)$ is the export of gas from the RoW to Europe

$ET(t)$ is total import demand for gas in Europe

s is the resource stock

n is the number of gas exporting countries

Eq. (N1) and (N2) are the first order conditions (FOC), which describe profit maximization strategies of Russia and the RoW, respectively. In contrast to Stigliz (1976) who incorporated monopoly into the Hotelling model, we depicts Russia as an oligopolist in the European gas market. We assume that Russia and the RoW play a non-cooperating game with a Nash equilibrium. By using an explicit demand function for import demand of gas in Europe, we derive the FOC as follows.

$$P1(t) + E1(t) * P1_{E1}(t) - C1_{E1}(t) = PR(t)$$

$$P1(t) + E1(t) * \frac{\partial P1(t)}{\partial ET(t)} * \frac{ET(t)}{P1(t)} * \frac{\partial ET(t)}{\partial E1(t)} * \frac{P1(t)}{ET(t)} - C1_{E1}(t) = PR(t)$$

$$P1(t) * \left(1 - \frac{SH1(t)}{ede}\right) = MC(t) + PR * (1 + r)^t$$

where

$$MC(t) = C1_{E1}(t)$$

$$PR(t) = PR * (1 + r)^t$$

$\frac{\partial ET}{\partial E1} = 1$ because we assume a Cournot oligopoly with a Nash equilibrium

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Eq. (N1) and (N2) shows the profit maximisation strategy of gas producers under an oligopolistic market structure. This implies that gas producers exercise market power to obtain the maximal profit. In the core model, marginal cost is assumed to be constant over time for Russia and the RoW. For the case where we consider a stock effect for Russia, Eq. (N3) is introduced in the model, which depicts the dependence of the marginal production cost on the remaining resource stock. The magnitude of the stock effect is depicted by a supply elasticity (es). Eq. (N4) and (N5) determine market shares of Russia and the RoW in the European gas market, respectively. Eq. (N6) shows the market clearing condition that determines the gas price. Eq. (N7) is the demand function for total imports of gas in Europe. Eq. (N8) is the demand function for domestic demand for gas in Russia. The domestic gas price is an exogenous variable because domestic prices are regulated in Russia. Eq. (9) is the intertemporal resource constraint. The numerical model is coded in General Algebraic Modelling System (GAMS) (Brooke et al., 1996) as a Mixed Complementarity Problem (MCP) and solved using PATH solver (Dirkse and Ferris, 1995). The model is calibrated based on data from Gazprom (2014b) and *New Policies Scenario* of World Energy Outlook 2013 (OECD/IEA, 2013). A more detailed description of the numerical model including the GAMS code as well as the calibration are presented in Appendix B, Supplementary data. To simulate the second gas agreement in the numerical model, we annually increase the export supply of gas from Russia to China (*e2*) by 30 bcm from 2018 until 2048.[7]

6. Results

6.1 Export supply and the resource constraint

Here, we want to show the implications of the second Russia-China gas deal under a binding and non-binding resource constraint by using the analytical and numerical model. To simulate an increase in the export supply of gas to China in the analytical model, we simply reduce the marginal production cost for supplying gas to the Chinese gas market. A reduction in marginal production cost should be thought of as an investment in infrastructure and the pipeline (i.e., the Altai pipeline), which enables supplying gas to China. Using the notation of the analytical model, we want to analyse the impacts on $\frac{dE1}{dA}, \frac{dE2}{dA}, \frac{dP1}{dA}, \frac{dP2}{dA}, and\ \frac{dPR}{dA}$.

The Business-as-Usual (BaU) is defined as the case where the second gas deal between Russia and China will not take place. Because we consider a finite planning horizon, two cases are possible: the resource constraint can be either binding or non-binding within the planning horizon: [8]

[7] In the numerical model, the export supply to China (*e2*) is an exogenous variable.
[8] Rolling planning horizon means a period, which Russia considers optimising its production strategy.

Case 1: $PR(t) > 0$ if $S(0) = \sum_{t=0}^{T} E1(t) + \sum_{t=0}^{T} E2(t) + \sum_{t=0}^{T} D(t)$

Case 2: $PR(t) = 0$ if $S(0) > \sum_{t=0}^{T} E1(t) + \sum_{t=0}^{T} E2(t) + \sum_{t=0}^{T} D(t)$

In the first case, the resource constraint is binding, meaning that the net price increases according to the well-known Hotelling path. The first case implies a small resource stock and a large planning horizon. In this case, all markets are connected via the resource rent, which depict the implicit cost (the opportunity cost) of gas extraction. The producer aims to equalise the marginal profit across markets. In the second case, the resource constraint is non-binding, meaning that the resource rent is zero.[9] The second case implies a large resource stock and a short planning horizon. The planning horizon could differ by country and resource sector. There may be many reasons why planning time horizon could differ. For example, risk aversion could be one explanation. Low-income countries tend to be more risk averse; they focus on short- and medium-term profits. Moreover, there are uncertainties regarding future demand for gas in Europe. Considering these two case reveals how a resource constrain may affect the bargaining on export supply of gas to Europe.

Below, we analyse the impacts of an increase in the export supply of gas from Russia to China under these two cases. For the sake of transparency, we ignore any stock effect as well as the impact on the domestic gas market in this part of the analysis because we focus on implications of resource constraint on the export markets. This simplification implies that

$$\frac{\partial C1(t)}{\partial S} = 0 \qquad \frac{\partial C2(t)}{\partial S} = 0 \qquad \frac{\partial CD(t)}{\partial S} = 0 \qquad \frac{\partial D(t)}{\partial S} = 0$$

Case 1: binding resource constraint

Totally differentiating Eq. (A1), (A2), and (A4) and making some algebraic manipulations, we obtain:

$$\frac{dE1}{dA} = \frac{\frac{dPR}{dA}}{\left(2*P1_{E1}+E1*P1_{E1,E1}-C1_{E1,E1}\right)} \tag{A6}$$

$$\frac{dE2}{dA} = \frac{\frac{dPR}{dA}+C2_{E2,A}}{\left(2*P2_{E2}+E2*P2_{E2,E2}-C2_{E2,E2}\right)} \tag{A7}$$

$$\sum_{t=0}^{T} \frac{dE1(t)}{dA(t)} + \sum_{t=0}^{T} \frac{dE2(t)}{dA(t)} + \sum_{t=0}^{T} \frac{dD(t)}{dA(t)} = 0 \tag{A8}$$

[9] Yet there are oligopolistic rents associated with the structure of gas markets.

Inserting Eq. (A6) and (A7) into (A8), we obtain:

$$\frac{dPR}{dA} = \frac{\sum_{t=0}^{T} \frac{-C2_{E2,A}}{(2*P2_{E2}+E2*P2_{E2,E2}-C2_{E2,E2})}}{\left(\sum_{t=0}^{T} \frac{1}{(2*P2_{E2}+E2*P2_{E2,E2}-C2_{E2,E2})}+\sum_{t=0}^{T} \frac{1}{(2*P1_{E1}+E1*P1_{E1,E1}-C1_{E1,E1})}\right)} > 0$$

This implies that

$\frac{dE1}{dA} < 0$ and $\frac{dP1}{dA} > 0$

$\frac{dE2}{dA} > 0$ and $\frac{dP2}{dA} < 0$

A reduction in the marginal production cost for supplying gas to China results in a higher export supply and a lower export price of gas to China. A higher export supply to China shrinks the available resource stock and thereby there is an increase in the resource rent. This is because gas reserves become scarcer. As a result, Russia will re-optimise its intertemporal profit maximization strategy by reducing export supplies to Europe.[10] An alternative interpretation is that due to scarcity Russia has an incentive to bargain for a higher gas price with Europe, when gas contracts will be re-negotiated. A higher gas price results in a lower demand for gas in Europe.

Below, we analyse the impacts of the second Russia-China gas deal on export supplies and gas prices, where the resource constraint is non-binding. Again, the justification for considering a non-binding resource constraint could be the availability of large gas reserves in Russia and a short planning horizon.

Case 2: non-binding resource constraint

$\frac{dE2}{dA} > 0$ and $\frac{dP2}{dA} < 0$

$\frac{dE1}{dA} = 0$ and $\frac{dP1}{dA} = 0$

In the case if the resource constraint is non-binding, the Asian and European gas markets are "disconnected" and there is no incentive to re-optimise export supplies to the European gas market. In other words, the implicit cost of supplying gas to China is zero under a non-

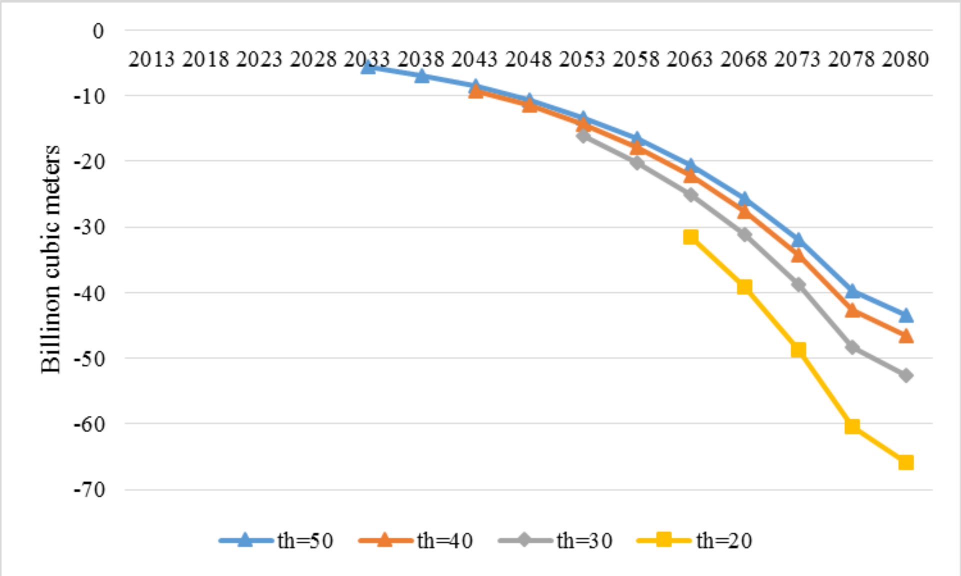
[10] Here, a re-optimisation means a change in the bargaining strategy by offering lower export supplies and/or bargaining for higher gas prices compared to BaU, when gas contracts are re-negotiated.

binding resource constraint. Hence, the equilibrium quantity and the price are determined solely by the explicit production cost and demand, which are not affected by other markets.

It should be noted that all changes in export supplies should be considered in the medium- and long-term. It is unlikely that there will be short-term supply responses because Russia exports gas under long-term contracts. On the other hand, gas contracts with some countries will terminate in the short-term so that re-negotiations will take place.

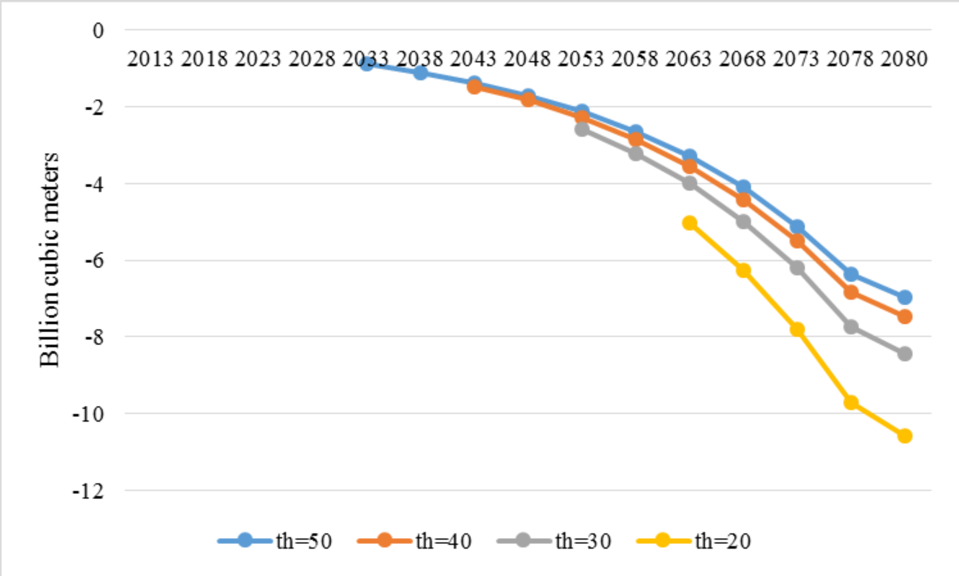
To demonstrate the implications of planning horizon, in the numerical model we increase the export supply of gas from Russia to China by 30 bcm annually from 2018 until 2048 under different planning horizons. On one hand, Russia may face a non-binding constraint at least in the medium term. On the other hand, gas is an exhaustible resource in the long term. Fig. 6 illustrates the impact of the second gas deal on the export supply to Europe. The figure shows the deviations from the BaU, where no gas deal is implemented. Fig. 7 reveals changes in total gas consumption in Europe associated with the second gas deal.

Fig. 6: Changes in gas exports from Russia to Europe under different planning horizons: deviations from BaU. a)



a) th=50, th=40, th=30 and th=20 state for a time horizon of 50, 40, 30 and 20 years, respectively.

Fig. 7: Changes in total gas consumption in Europe under different planning horizons: deviations from BaU.



The main point is that Russian gas exports to China will ultimately result in lower export supplies to Europe because gas is an exhaustible resource. Gas exported to China could have potentially supplied Europe in the future. The length of planning horizon determines when Russia will start re-optimising its export supplies. For example, when we assume that Russia plans its investment decisions and export supplies for 30 years, there is no reduction in export supplies of gas to Europe until 2051 because the resource constraint is non-binding. The economy is in a non-scarcity phase. In other words, scarcity is not an issue so that there is no incentive to re-optimise export supplies. In fact, a reduction in the export supply to Europe is sort of "postponed" into the future. The short the planning time horizon, the later the reduction in export supplies to Europe will take place. A finite time horizon lead to inefficiency in the extraction path.

In contrast, after 2051 Russia faces a scarcity phase. The resource constraint becomes binding; Russia becomes more concerned regarding resource scarcity and it switches its intertemporal profit maximisation strategy to a "Hotelling mode", i.e., the model operates as a standard Hotelling model. Again, gas exports to China reduce total Russian gas reserves, which potentially could supply the European gas market in the future. As a result, there are reductions in the export supply of gas from Russia to Europe in the long term, depending on the planning horizon assumed.[11] Reductions in the export supply becomes more pronounced over time because of discounting. An alternative interpretation of the result is that Russia will take a tougher bargaining strategy regarding the gas price and quantity; a higher gas price will lead to a lower demand for gas in Europe.[12] Resource scarcity forces Russia for a tougher bargaining position. It should be noted that export supplies would be even lower if Russia will continue to export gas to China after 2048. Reductions in export supplies of gas from Russia lead to a lower consumption of gas in Europe. Because we assume perfect substitutability between gas imports, Russian gas is partially replaced by gas from other countries. Therefore, other gas exporters benefit from a reduction in Russian gas export supplies to Europe, which results in higher gas prices. Overall, decreases in total gas consumption in Europe are less than reductions in the export supply of gas from Russia to Europe due to high substitutability between gas imports (Fig. 7). For example, an annual average reduction in total consumption of gas in Europe under planning horizon of 30 years accounts for approximately 5 bcm for period from 2051 until 2080.

6.2 Export supply and the stock effect

In the previous section, we ignored any “stock effect”. In reality, there may be a stock effect, where marginal production cost depends on the remaining stock (Lin et al., 2008). In other words, a stock effect implies explicit production costs. In the numerical model, a stock effect is depicted by a supply elasticity (Section 5.2). A stock affect could be another factor that forces Russia to re-optimise its intertemporal profit maximisation strategy. Therefore, we consider a third case (Case 3), where the resource constraint is non-binding, but there is a stock effect. When extraction increases, the remaining stock shrinks so that marginal production cost increases. Given the assumption of a stock effect, an increase in the export supply of gas to China will have an impact on export supplies to Europe via an increase in marginal production cost:

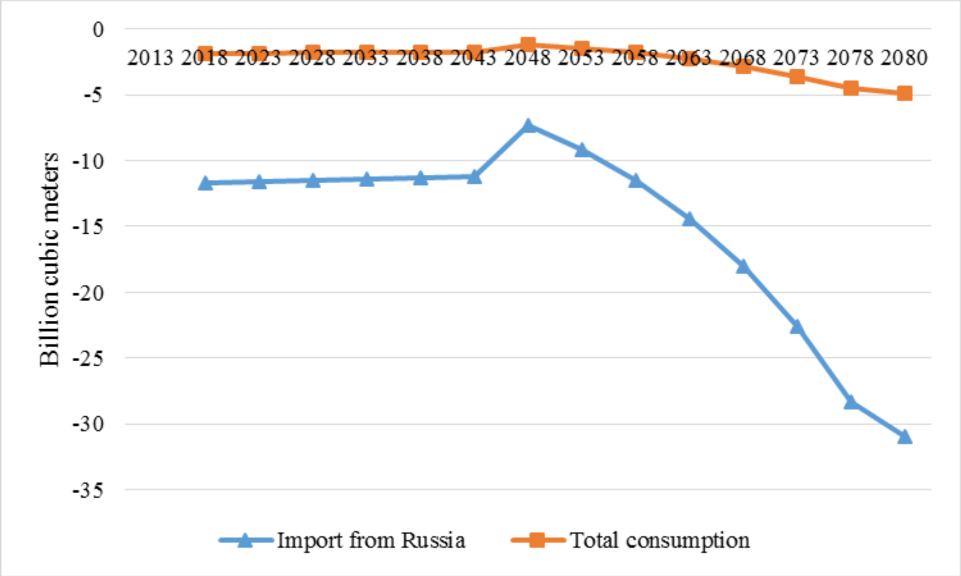
$$\frac{dE1}{dA} = \frac{C1_{E1,S} * \frac{dE2}{dA}}{\left(2 * P1_{E1} + E1 * P1_{E1,E1} - C1_{E1,E1} - C1_{E1,S}\right)} < 0 \qquad \text{and} \qquad \frac{dP1}{dA} > 0$$

[11] Both gas agreements between Russia and China are planned for 30 years. Therefore, 30-35 years may be a reasonable rolling planning horizon for Russia.

[12] One interpretation of the results is that Russia will reduce its export supplies and another interpretation is that Russia will bargain for higher gas prices. In fact, the outcome is the same: there will be a higher price and a lower quantity compared to BaU.

Even with a non-binding resource constraint (i.e., no scarcity concerns), Russia will re-optimise its export supply to Europe because of a higher marginal production cost. In other words, in the presence of a stock effect Russia would bargain for a higher gas price with European gas consumers. The magnitude of the stock effect determines how strong the gas price will increase. Fig. 8 shows reductions in the export supply to Europe and total gas consumption under a planning horizon of 35 years and a stock effect.

Fig. 8: Changes in gas exports from Russia to Europe and total gas consumption in Europe under a planning horizon of 35 years and a stock effect: deviations from BaU.



From 2018 until 2047, the stock effect results in a reduction in the export supply of gas from Russia by approximately 12 bcm. After 2018, in addition the stock effect there is a strong decrease in the export supply associated with the resource constraint. Nevertheless, decreases in total consumption of gas in Europe are moderate because of high substitutability between different gas imports. The annual average reduction in total consumption of gas in Europe from 2018 until 2080 accounts for approximately 2.3 bcm (Fig. 8).

To sum up, scarcity concerns and a stock effect could force Russia to re-optimise its intertemporal profit maximisation strategy in the European gas market in the medium- and long-term, by reducing export supplies or/and bargaining for higher gas prices. While a stock effect could affect export supplies in the medium-term, scarcity tends to have rather a long-term impact depending on the finite planning horizon.

6.3 Export supply and the domestic gas market

In the previous section, for the sake of transparency we focused on export gas markets only, yet the role of domestic gas market should not be neglected. We assume that the domestic gas price is regulated in Russia and is lower than export netback prices. The (socially) optimal gas price should be equal the marginal production cost: $pd = CD_D + PR$. Under a non-binding resource constraint and without any stock effect, an increase in the domestic gas price would not lead to any re-optimisation of export supplies. In other words, there would not be changes in export supplies:

$$\frac{dE1}{dpd} = 0 \qquad \text{and} \qquad \frac{dP1}{dpd} = 0$$

$$\frac{dE2}{dpd} = 0 \qquad \text{and} \qquad \frac{dP2}{dpd} = 0$$

In contrast, given the assumption of a binding resource constraint and without any stock effect, increasing the domestic gas price would result in a lower resource rent:

$$\frac{dPR}{dpd} = \frac{\sum_{t=0}^{T} -D_{PD}}{\left(\sum_{t=0}^{T}\frac{1}{(2*P2_{E2}+E2*P2_{E2,E2}-C2_{E2,E2})}+\sum_{t=0}^{T}\frac{1}{(2*P1_{E1}+E1*P1_{E1,E1}-C1_{E1,E1})}\right)} < 0$$

Intuitively, a lower domestic demand for gas provides additional gas, relaxing the scarcity constraint. As a result, Russia will re-optimise its intertemporal profit maximization strategy in the export markets, by increasing export supplies to both export markets:

$$\frac{dE1}{dpd} = \frac{\frac{dPR}{dpd}}{(2*P1_{E1}+E1*P1_{E1,E1}-C1_{E1,E1})} > 0 \qquad \text{and} \qquad \frac{dP1}{dpd} < 0$$

$$\frac{dE2}{dpd} = \frac{\frac{dPR}{dpd}}{(2*P2_{E2}+E2*P2_{E2,E2}-C2_{E2,E2)}} > 0 \qquad \text{and} \qquad \frac{dP2}{dpd} < 0$$

It should be noted that increases in export supplies might be even more pronounced in the presence of a stock effect. This is because a lower supply to the domestic gas market results in a higher remaining stock and thereby a lower marginal production cost.

To illustrate the potential of the domestic gas market, we increase the regulated domestic gas price in the numerical model. In 2013, Gazprom sold approximately 228.1 bcm of gas in the domestic market at a price of $106.7/thousand cubic meters (tcm). Fig. 9 shows reductions in the domestic gas demand associated with increases in the domestic gas price. The core values of the price elasticity of domestic demand for gas in Russia is assumed to be -0.50. The planning time horizon is assumed to be 35 years. Fig. 10 reveals reductions in the domestic demand for gas associated with a 20% increase in the domestic gas price under different price elasticities of domestic demand for gas in Russia.

Fig. 9: Reductions in the domestic demand for gas in Russia under different price increases: deviations from BaU.

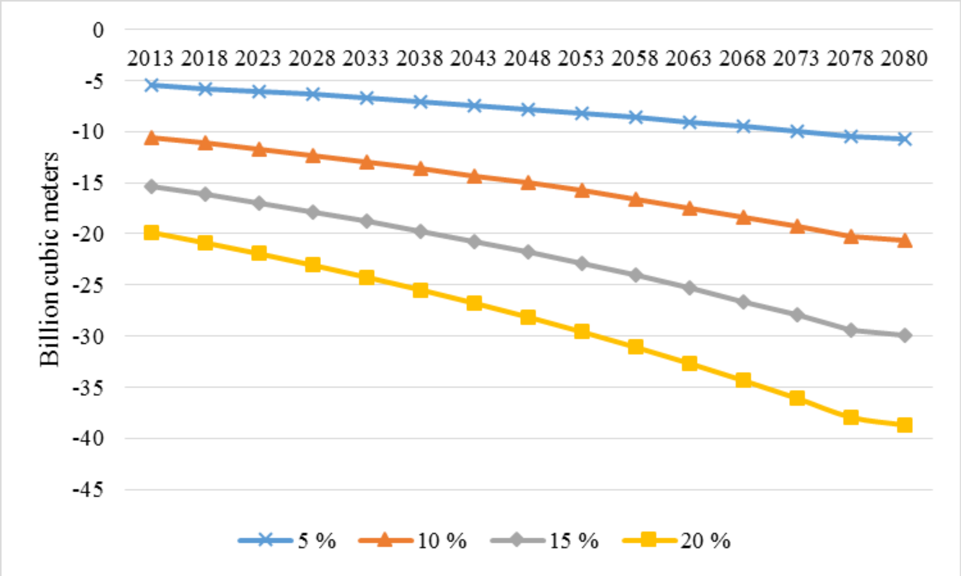
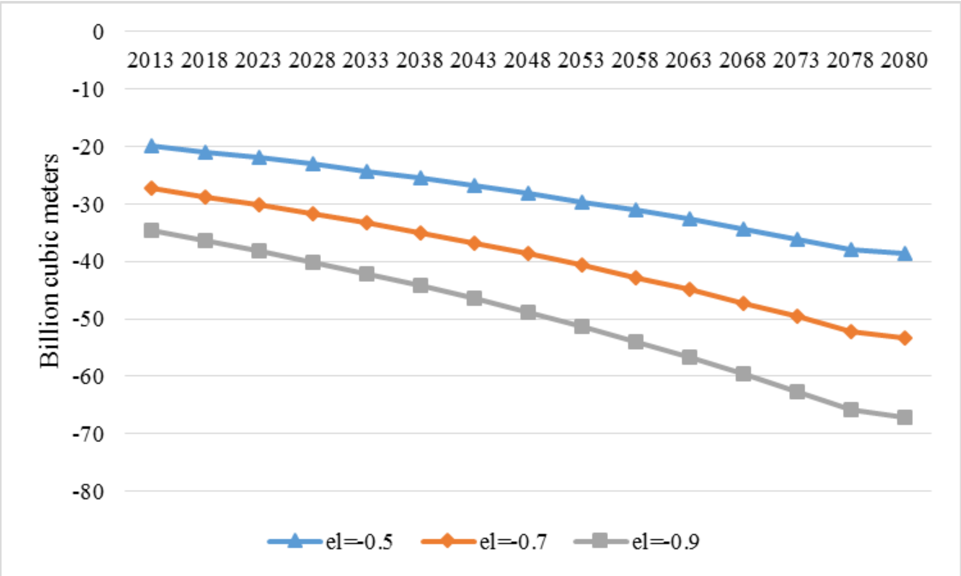


Fig. 10: Reductions in the domestic demand for gas in Russia resulting from a 20% increase of the domestic gas price under different price elasticities of domestic demand: deviations from BaU.

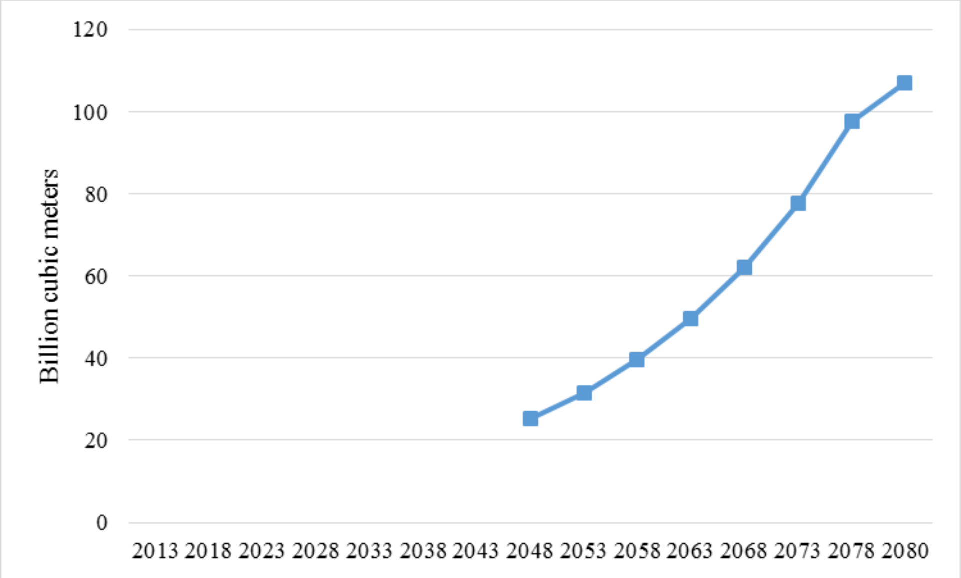


An increase in the domestic gas price could release a substantial amount of gas. For example, under a price elasticity of demand equalling -0.5, a 20% increase in the domestic gas price results in an annual average reduction of domestic demand for gas by approximately 29 bcm (Fig. 10). This is nearly the amount of gas to China according to the second gas agreement (30 bcm). The reductions in domestic demand become larger over time because of increases gas consumption. The domestic demand for gas is assumed to be inelastic, meaning that increases in the price are relatively more pronounced than reductions in the quantity. The larger the price elasticity of demand, the more pronounced the reduction in domestic demand (Fig. 10).

The share of gas in total energy consumption is large in Russia. Therefore, even a relatively small reduction in gas consumption provides a substantial amount of gas in absolute terms. Regulation of domestic gas prices operates as an implicit subsidy. The Russia-China gas deal may raise incentives to move towards a more efficient gas pricing in Russia. As a result, Russia could reduce the distortion resulting from domestic gas subsidies, and at the same time reduce scarcity concerns and adverse stock effects. The domestic gas market provides a large reserve for further export supplies. The potential of the domestic gas market becomes even more important in the presence of capital constraint (e.g., western sanctions and imperfect capital mobility). Gazprom could have difficulties to finance the Altai and Power of Siberia pipelines. Gas price reform may raise the money needed to finance these pipeline projects. Indeed, the Russian government has planned to eliminate the regulation of domestic wholesale gas prices, but gas price reform has been postponed for a long time mainly due to increases in the oil price as well as the economic crisis. Furthermore, an increase in domestic gas price tends to have an adverse income distribution impact, which should not be neglected.

Fig. 11 reveals the increase in the export supply of gas to Europe associated with a 20% increase in the domestic gas price in Russia with a price elasticity of domestic demand equalling -0.50 and a time horizon of 35 years, with no stock effect assumed.

Fig. 11: The increase in the export supply of gas from Russia to Europe under a 20% increase of the domestic gas price in Russia: deviations from BaU.



Because we assume a finite planning horizon and no stock effect, there is no changes in the export supply of gas to Europe until 2048. There is no incentive to change the intertemporal profit maximization strategy in the European gas market. After 2048, Russia re-optimises its export supplies to the European gas market, by increasing its export supply to Europe. One could think that Russia has market power in the European gas market so that the domestic gas market would unlikely affect export supplies. Nevertheless, a reduction in the domestic demand for gas decreases resource scarcity, allowing for additional export supplies. As a result, Russia will increase the export supply to Europe. Furthermore, in the presence of a stock effect, increases in the export supply to Europe would be more pronounced because a lower domestic demand would reduce the marginal production cost. The annual average increase in the export supply of gas from Russia to Europe from 2048 until 2080 accounts for approximately 56.5 bcm.

6.4 Bargaining, market power and the resource constraint

The results from the theoretical and numerical model in the previous section shows that if the gas producer has a large resource stock and use a finite planning horizon, the resource constraint may be non-binding, implying zero scarcity rents. Indeed, Russia has large reserves of natural gas. Moreover, the domestic gas market provides a huge potential for increasing gas exports. Therefore, Russia can increase export supplies to other countries, without reducing its export supplies to European economies, at least in the medium term. Another important factor is the market structure. For example, if we assume that Russia is reluctant to the resource constraint, then European gas prices will not affect the profit maximization strategy in the Chinese gas market. In other words, the European gas market does not raise any opportunity cost for supplying gas to China. Russia will bargain with China for a combination of price and quantity, which will maximise the profit. One important conclusion, which we can derive from the analytical model, is that gas prices for Europe and China should differ regardless, whether the resource constraint is binding or not. Given the assumption of equal marginal production costs, the static efficiency conditions (Eq. (A1) and (A2)) can be written as follows:

$$P1(t) + E1(t) * P1_{E1}(t) = P2(t) + E2(t) * P2_{E2}(t)$$

We see that the gas prices likely would differ due to different degrees in market power; gas producers aim to equalise the marginal profit from markets and not the prices. The optimal profit maximising price is determined by the market share and the price elasticity of demand, which reflects the Chinese willingness to pay for additional gas. The ratio between the export netback price for Europe and China can be calculated as follows. Using explicit demand functions, Eq. (A1) and (A2) can be combined to obtain:

$$P1(t) * \left(1 - \frac{SH1(t)}{ede1}\right) = P2(t) * \left(1 - \frac{SH2(t)}{ede2}\right)$$

$$\frac{P1(t)}{P2(t)} = \frac{\left(1 - \frac{SH2(t)}{ede2}\right)}{\left(1 - \frac{SH1(t)}{ede1}\right)}$$

where $ede1$ is the price elasticity of demand for gas in Europe

$ede2$ is the price elasticity of demand for gas in China

The share of Russian gas in the European gas market is approximately 30%, in the Chinese gas market it is 1%. Moreover, the Chinese demand for gas may be more elastic than European one. The smaller the market share and the higher price elasticity of demand, the smaller gas price should be. A price elasticity of demand indicates the ability of consumers to pay.

Furthermore, resource scarcity is an important strategic value in bargaining process. Scarcity could affect bargaining strategies on the European and Asian gas market. Producers and consumers usually take some benchmark prices as the point of departure in bargaining. For example, for China a benchmark price could be the price, which it pays for Turkmenistan gas. For Russia, a benchmark price could be the average export netback price for Europe (Henderson, 2014). Obviously, if Russia was a price-taker in the European gas market, the opportunity cost of supplying additional gas to China is simply the average price of gas for the European gas market. Yet Russia could affect gas price in Europe due to market power. A reduction (an increase) in export supplies to Europe will potentially lead to a higher (lower) gas price. Therefore, the current European price of gas may not reflect the real opportunity cost for supplying additional gas to China.

Resource constraint has an impact on bargaining strategies. Large gas reserves may make Russia less tough in bargaining with China regarding the gas price. In contrast, under a binding resource constraint, Russia would be keener to equalise marginal profit between both markets. Yet some resource rents may be scarified for the sake of energy security (i.e., energy diversification). Whether the second gas deal between Russia and China will strengthen the Russian bargaining position against Europe is not obvious, this probably depends on the yet-to-be-agreed gas price. Gazprom bargains on prices and quantities not with Europe as a whole, it bargains with certain countries on a bilateral basis. If China will offer a price that is high enough to provide a benchmark for further re-negotiations of gas contracts with European markets. A low gas price for China is unlikely to provide real bargaining power for Russia.

7. Conclusions

At the end of 2014, Russia and China signed a framework for the second gas agreement. According to this agreement, Russia will supply 30 bcm annually over 30 years to China through the Altai pipeline. The gas price is still under negotiation. The Altai pipeline enables Asian and European gas markets to connect. In this paper, we analyse strategic implications of the second gas agreement on the European gas market. Our analysis is based on an analytical and numerical Hotelling model. The main findings are as follows:

1) Due to different degrees of market power, it is economically rational for Russia to implement price discrimination among different gas consumers. Therefore, the export netback price of gas for China should not necessarily be equal to European export netback prices. This holds true even if the resource constraint is binding. The export

price for China tends to be lower than that for Europe because Russia has a smaller market share in the Chinese gas market. Moreover, the Chinese demand for gas may be more elastic than the European one.

2) Given the assumption of a finite planning horizon and that large gas reserves are available in Russia for a long period (at least until 2050), Russian gas producers likely face a non-binding resource constraint. Indeed, Russia has the potential to provide additional gas to China, without reducing export supplies to Europe. Currently, Russia has even had an oversupply of gas. Under a non-binding resource constraint, there is no incentive to re-optimise the intertemporal profit maximisation strategy in response to gas exports to China. Therefore, the second gas agreement between Russia and China will unlikely result in lower export supplies of gas to European economics, at least in the medium-term (e.g., 30-35 years). Nevertheless, gas exports to China will ultimately reduce the potential of Russia to export gas to Europe in the long-term. Our results show that Russia could take a stronger bargaining position after 2050, when scarcity concerns could become more pronounced. Overall, reductions in total gas consumption in Europe are moderate because of high substitutability between different gas imports.

3) A stock effect, which occurs when the marginal production cost is affected by the remaining stock, may force Russia to re-optimise its intertemporal profit maximisation strategy in the European gas market, even in the medium term. Supplying additional gas to China results in a lower remaining stock, which could result in a higher marginal production cost. Therefore, Russia has an incentive to bargain with Europe for a higher gas price to compensate for increases in the marginal production cost. How strong the price increase may be, depends mainly on the magnitude of a potential stock effect. Under a price elasticity of supply equalling unity, the stock effect could lead to a reduction in the export supply to Europe by approximately 12 bcm.

4) Nevertheless, adverse stock effects and scarcity concerns may be fully or partially reduced if domestic gas subsidies are eliminated in Russia. Domestic gas prices are regulated in Russia and are substantially lower than export netback prices. Price regulation operates as an implicit domestic subsidy. The domestic gas market covers a large potential for export supplies. For example, a 20% increase in the domestic gas

price could release approximately 29 bcm of gas annually, which could be exported. Increasing domestic gas prices enables Russia to rebalance its export supplies and to accumulate funding required for building pipelines. Indeed, the Russia government aims to increase domestic wholesale gas prices in the medium-term. Gas price reform in the domestic gas market becomes even more relevant in the course of capital constraints (e.g., imperfect capital mobility and western sanctions).

5) The second gas deal between Russia and China may strengthen the bargaining position of Russia if China offers a gas price that is high enough to provide a benchmark for further re-negotiations of gas contracts with European markets. A low gas price for China could unlikely provide a real bargaining power for Russia.

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