UNDERSTANDING THE LACK OF COMPETITION IN NATURAL GAS MARKETS: THE IMPACT OF STORAGE OWNERSHIP AND UPSTREAM COMPETITION

Michal Mravec

CERGE-EI

Charles University
Center for Economic Research and Graduate Education
Academy of Sciences of the Czech Republic
Economics Institute

WORKING PAPER SERIES (ISSN 1211-3298)
Electronic Version

342

Working Paper Series 342
(ISSN 1211-3298)

Understanding the Lack of Competition in Natural Gas Markets: The Impact of Storage Ownership and Upstream Competition

Michal Mravec

CERGE-EI
Prague, September 2007

ISBN 978-80-7343-141-9 (Univerzita Karlova. Centrum pro ekonomický výzkum a doktorské studium)
ISBN 978-80-7344-130-2 (Národohospodářský ústav AV ČR, v.v.i.)

Understanding the Lack of Competition in Natural Gas Markets: The Impact of Storage Ownership and Upstream Competition

Michal Mravec*

CERGE-EI**

September 2007

Abstract

Motivated by the failure of competition to emerge after the natural gas market in the Czech Republic was liberalized, I explore the impact of natural gas storage ownership and upstream competition on the downstream level. I extend standard Cournot models to understand current and likely future developments, paying particular attention to the impact of market liberalization on a country characterized by a lack of domestic production, limited foreign upstream competition, and highly concentrated (and bundled) control over an essential input in the production of the final product: gas storage. I show that the upstream producer may practice his market power to capture some of the benefits of liberalization and increase the wholesale price, which hinders the desired decline of the end-user price in the long run. This pricing change in turn makes the entry of new players in the transition period more difficult. I furthermore analyze three prominent storage structure scenarios and conclude that higher consumer welfare can be reached only in the case of regulated storage access.

JEL classification: D42, D43, L11, L12, L13, L51
Keywords: natural gas, liberalization, deregulation, successive oligopoly, monopoly, Czech Republic, gas storage

---

Thanks are due to Andreas Ortmann and Sergey Slobodyan for their guidance and insightful comments. I would also like to thank Libor Dušek, Avner Shaked and Markéta Mravcová for their help. This research was supported as a part of the REFGOV Integrated project funded by the 6th European Research Framework Programme - CIT3-513420.

* Junior Researcher at the Economics Institute of the Academy of Sciences of the Czech Republic, CERGE-EI doctoral student; email: michal.mravec@cerge-ei.cz

** CERGE-EI is a joint workplace of the Center for Economic Research and Graduate Education, Charles University, and the Economics Institute of the Academy of Sciences of the Czech Republic. Address: CERGE-EI, P.O. Box 882, Politických vězňů 7, Prague 1, 111 21, Czech Republic

Abstrakt

Ve své práci, která je motivována nedostatkem konkurence na trhu se zemním plynem po otevření trhu v České republice, zkoumám dopad vlastnictví zásobníků zemního plynu a struktury upstreamové těžby na domácí trh. Rozšířením standardních modelů hospodářské soutěže a lá Cournot se snažím porozumět současnému a možnému budoucímu vývoji, přičemž se zaměřuji zejména na dopad liberalizace trhu na zemi, která se potýká s nedostatkem domácí produkce, omezenou konkurencí zahraničních těžebních společností a vysoce koncentrovanou (a provázanou) kontrolou nad zásobníky plynu, které jsou klíčovým vstupem při výrobě koncového produktu. Ukazuji, že upstreamový výrobce může využít své tržní síly k získání části přínosů liberalizace a zvýšit tak velkoobchodní ceny, což v dlouhodobém horizontu omezuje žádoucí snížení koncové ceny. V důsledku této změny cen je i vstup nových obchodníků na trh v přechodném období obtížnější. Dále zkoumám tři významné scénáře s různou strukturou skladovacích služeb a docházím k závěru, že pro spotřebitele může být liberalizace výhodná pouze při regulovaném přístupu k zásobníkům.

1 Introduction

Liberalization of monopolistic markets is meant to increase consumer welfare, eliminate (or at least reduce) the need for market regulation, provide equal opportunities for companies, and enhance economic efficiency. With these objectives in mind, a liberalization process is under way in the European Union in the markets for electricity and natural gas, aiming ultimately at the creation of a single liberalized internal market. However, the interim results are far from what was hoped for. In many EU member states, energy prices are increasing and markets can hardly be described as competitive.

Here I focus on the situation in the natural gas market in the Czech Republic, which has experienced an increase in prices and no entry of additional suppliers after the first step towards market opening in 2005 and subsequently even saw the re-introduction of regulation in 2006. At the time of writing this article, when the market was officially liberalized and all customers were allowed to choose their supplier, the market continued to be dominated by the incumbent and consumers had virtually no choice of supplier.

In light of these developments, I analyze two factors that are likely to contribute to the failure of competition to emerge in the Czech Republic, as well as other countries characterized by similar features. I focus on 1) the fact that the Czech Republic is almost completely dependent on foreign gas imports that come from an upstream market with a very small number of producers; and 2) the fact that storage facilities, an essential component in the production of the final product, are almost completely controlled by the incumbent. I extend standard Cournot models to understand configurations such as these.

My models demonstrate that import dependency and limited upstream competition impede efficient market liberalization in the long-run due to a change in upstream pricing after end-user price regulation is revoked. This has also implications for the transition period, i.e., the period before the contracts (and thus also prices) concluded before liberalization by the established players expire, in which it is difficult for new traders to buy gas at competitive wholesale prices. Efficient market liberalization is further inhibited by concentrated ownership of gas storage structure; unbundling of ownership cannot overcome these impediments. These results stem from comparisons of the pre-liberalization steady state with long-run steady states achieved under various scenarios of the liberalized setup after all players adjust to the structural changes of the market.

The remainder of this article is organized as follows: In section 2, I describe the stylized facts that motivated my inquiry. Section 3 reviews the existing literature and its deficiencies. Section 4 explains the key models. Section 5 provides a discussion of the results to be gleaned from these models. Section 6 concludes.

2 The Czech Natural Gas Market

Until recently the Czech natural gas industry was a state owned and regulated monopoly. This was in line with the belief that this sector exhibits features of natural monopoly and that it would not be economically sensible to have parallel pipelines built and operated by different companies. In 2002, the whole sector was privatized and the majority (the bundled transmission system and storage system operator and importer and six out of the total of eight distribution companies) was sold to the German company RWE.[1] In line with EU Directive 2003/55/EC and the Czech Energy Act, the incumbent was forced to implement the legal unbundling of its activities, i.e., to separate physical transmission and import, physical distribution and sale,[2] and to provide network services (transmission and distribution) to other gas companies on a non-discriminatory basis. This strategy corresponds to the basic idea of liberalization that one can continue to capture the economies of scale arising from a single network, but can do better overall by introducing competition into trading, thus eliminating the need for regulation of some activities and reducing the final price for consumers through competition.

The opening of the Czech natural gas market was a stepwise process which started in January 2005 by letting the 35 largest consumers choose their supplier while other consumers continued to purchase gas from the incumbent for regulated prices. In

---

[1] In this paper I will use the term incumbent to refer to the companies of the RWE Group.
[2] The joint importer and transmission system operator was obliged to unbundle starting January 1, 2006. The distribution companies were obliged to unbundle into distribution system operators and traders-sellers starting January 1, 2007.

January 2006 all commercial customers became "eligible."[3] Full market liberalization[4] was achieved in the beginning of 2007.

Following the first step, natural gas prices for eligible customers increased, which prompted them to file complaints with the Energy Regulatory Office which in turn responded by re-introducing regulation of prices offered by the incumbent to eligible customers starting January 1, 2006 for the period of one year. Since disaggregated profit data are not publicly available, it is unclear whether natural gas prices increased due to the sharp parallel increase in oil prices, to which long-term natural gas contracts are indexed – an explanation advocated by the incumbent – or whether the incumbent tried to extract extra profits. While other explanations are possible, the response of the Czech regulator – which does have access to the disaggregated data – can be read as an indication that the regulator believed that the liberalization process was not working the way it was supposed to work.

Indeed, had the liberalization plans worked as intended, new traders should have entered the market, a non-negligible number of consumers should have switched to new suppliers (or at least new consumers should purchase gas from new traders) and the end-user price should have declined. However, this did not happen. The largest entrant[5] claims, as of the writing of this paper, to have imported 100 million cubic meters of natural gas since October 2006, or approximately 1% of the annual consumption in the Czech Republic and less than 1.5% of the Czech winter[6] consumption. Interestingly, this entrant is partially owned by the Russian upstream producer Gazprom which naturally raises the question whether it was just this strategic alliance that enabled it to enter the market.

In order to thoroughly understand the situation, two more facts seem of importance. Firstly, the Czech Republic is almost completely dependent on imports of natural gas,[7] with Russia being the dominant supplier covering about 75% of the domestic consumption and Norway with its 25% share lagging far behind. The extent to which duopolistic competition takes place between these two producers is questionable,

[3] The eligible customer is a customer who is allowed to freely choose a gas supplier.

[4] Here, the term full market liberalization refers to the fact that all customers became eligible, not to be mistaken for a fully functioning and competitive market.

[5] Vemex

[6] October to March

[7] The Czech Republic covers approximately 1% of its consumption by domestic production.

as the decision to buy gas from Norway was a politico-strategic decision made by the Czech government before privatization, notwithstanding the fact that buying gas from Russia would have been cheaper (at that point). Importantly, long-term take-or-pay contracts with these producers, which were written before liberalization, are in place; they are scheduled to expire in the middle of the next decade.[8]

The second important fact is that storage, which is an essential input for the production of the final product used to cover seasonal and day-to-day fluctuations in gas consumption, is almost completely controlled by the incumbent, who owns 6 storage facilities and has long-term lease contracts for the remaining storage used for the Czech Republic. Although there are some tools which the Czech authorities may use (and do use) to control the storage price and access to storage, such as penalties in case that the incumbent abuses its dominant position, there is no direct regulation mechanism established. Due to this the storage structure lies somewhere between the regulated access and the incumbent's monopoly.

3 Existing Literature

My models below are based on standard industrial organization models of Cournot and Stackelberg competition (e.g., Tirole (1988), Shy (1995)). A relevant variant of these models was formulated by Greenhut and Ohta (1979), who use a market structure consisting of an upstream and downstream level – successive oligopoly – to investigate the effects of vertical integration.

The literature on energy markets, and in particular on natural gas markets, often draws on a structure based on the two-level model of Greenhut and Ohta (1979). Various authors investigate this market either using numerical models to simulate a large and complex market or focusing on a smaller part of the market and finding closed-form solutions. The first and more numerous group of authors includes Golombek and Gjelsvik (1995), Golombek et al. (1998), Boots et al. (2004), Holz and Kalashnikov (2005) and Egging and Gabriel (2005), who calibrate and numerically solve simulation models of the market with natural gas. The most relevant paper with closed form solutions is Nese and Straume (2005) (and the work of Greenhut and Ohta

[8] The contract with Russia expires in 2014; the contract with Norway expires in 2017.

(1979) which, however, is not formulated specifically for the natural gas market and therefore cannot be immediately applied.).

Golombek and Gjelsvik (1995) develop a numerical model for six Western European countries investigating the effects of radical liberalization. After calibrating the model (demand elasticities, costs, etc.), in which agents compete Cournot style, and numerically solving it, the authors conclude that the biggest winners of liberalization will be the end-users whose consumer surplus will increase significantly, while profits to producers, transporters and distributors will decline. However, the authors do not consider obstacles, such as upstream market power and storage structure, and their detrimental impact on the post-liberalization development.

Golombek et al. (1998) use a numerical model with Cournot competition on the production (upstream) level and regulated returns on lower levels, investigating in particular the effect of liberalization on the upstream production. The authors claim that after market liberalization and break up of former monopolies, it will be optimal for gas producing countries to break up their producing consortia. However, no formal proof or closed form solutions are specified.

Boots et al. (2004) (and their full report Boots et al. (2003)) formulate a model of the natural gas market which has a structure of a successive oligopoly, i.e., they assume oligopolistic competition both on the side of traders as well as producers. Drawing on the notion of double marginalization (e.g., Tirole (1988), Spengler (1950)), they assume that producers anticipate the behavior of traders and maximize producer profits given the traders' actions. In addition to being able to distinguish between countries, producers are also able to distinguish between market segments. Their empirical model (called GASTALE) is very ambitious in the sense that the authors calibrate it to capture a market including several Western European countries and use numerical non-linear programming solvers to obtain the results. That means that there are no closed form expressions presented for prices, quantities, etc. Furthermore, no comparison is made with the situation when gas supply on the domestic market is regulated.

Holz and Kalashnikov (2005) have a similar approach to Boots et al. (2004), however, they consider iso-elastic demand functions. Using their own simulation model they analyze double marginalization and perfect competition scenarios.

Egging and Gabriel (2005) realize how market power could be detrimental to the consumers and set up a model in which foreign gas producers can adjust their production levels to alter the end-user price. However, instead of using a successive oligopoly approach with traders, producers directly consider the downstream demand. Storage is explicitly modeled, however, storage operators are considered perfectly competitive and have no market power.

Moving to literature with closed-form solutions, Nese and Straume (2005) use a successive oligopoly structure with two upstream producing countries, which they believe has the highest relevance in particular for the European natural gas market, to analyze strategic behavior of policy makers in setting taxes. Their results are interesting in that they show how a decision on one level influences the other level and the wholesale and end-user price. However, their paper, which focuses primarily on strategic trade policy, does not consider gas storage, downstream costs other than the wholesale price and a tax, and market liberalization.

The presented natural gas market studies fail to provide a clear comparison of the regulated and liberalized situations using closed form solutions which would allow for the identification of the cause of the problems. Furthermore, most do not capture the real existing situation in the storage sector (in particular in the Czech Republic) or completely miss this crucial component of natural gas supply, for which the empirically observed as well realistically contemplated structure should be considered.[9] My investigation addresses these issues using a full two-tier successive oligopoly structure augmented with storage and makes a direct comparison of the situation before and after liberalization, allowing me to identify and analyze problems associated with market opening.

4 The Models

I abstract from the fine structure of the natural gas industry by classifying companies engaged in trading activities (import and sale to customers) as traders and

[9] Egging and Gabriel (2005) consider perfectly competitive and capacity constrained storage. Golombek and Gjelsvik (1995) and Golombek et al. (1998) use fixed storage prices derived from the standard rate of return, which is common in the natural gas sector. Boots et al. (2004) use a similar approach. Holz and Kalashnikov (2005) and Nese and Straume (2005) do not consider storage at all.

the transmission and distribution system operators as a single entity providing the physical transportation of gas to the customers. This abstraction enables me to use models of successive oligopoly (e.g., Greenhut and Ohta (1979), Nese and Straume (2005)) that involve two levels of competition only. Approximating the relevant scenario for the Czech Republic, I assume the upstream segment to consist of a single producer[10] while the configuration of the downstream segment depends on the discussed scenario.

In the first section I focus on the impact of limited upstream competition on market liberalization while in the second section I analyze various storage configurations. In each section I start with a benchmark model of the market before liberalization. I then compare the post-liberalization scenarios with the benchmark case. The post-liberalization scenario models are not necessarily intended to capture the current situation on the market; instead, they describe a situation after liberalization has been achieved, e.g., after new traders have entered the market. The comparisons of the scenarios before and after liberalization provide hints why it might be difficult to achieve the outcomes that liberalization was to bring about.

I use Cournot competition in quantities to model the behavior of n players on the downstream market. This approach is in line with much of the literature on the economics of natural gas (see e.g., Nese and Straume (2005); Boots et al. (2004); Holz and Kalashnikov (2005); Golombek and Gjelsvik (1995)) and corresponds to the physical organization of the market and the way how gas supply is secured. When purchasing gas, traders not only have to contractually arrange for the commodity, but they also have to book the corresponding transmission and storage capacities, which are often limited, in order to serve the customer. Therefore, Bertrand competition in prices would not be feasible since it assumes that a trader can readily sell as much quantity as the consumers demand at the price set by the trader. The introduction of capacity constraints into Bertrand competition does solve this issue, however, it leads to the problem of how to assign capacity limits to individual traders**.** Furthermore, Kreps and Scheinkman (1983) analyze two-stage duopolistic competition with quantity precommitment in the first stage followed by Bertrand competition in the second stage

[10] It can be shown that in the case of an upstream duopoly, the effects are similar – identical in terms of the directions, but smaller in magnitude; see Mravec (2006).

and show that under fairly weak assumptions, which are satisfied by the linear downward sloping demand function used in this research, Bertrand competition leads to Cournot outcomes; hence, we might as well model Cournot competition directly.

Following well-established practice in the existing literature (e.g., Nese and Straume (2005); Boots et al. (2004); Holz and Kalashnikov (2005)), I assume that the upstream producer establishes, in a Stackelberg like manner, his pricing strategies contingent on the downstream structure. The solution strategy is thus as follows: downstream traders compete à la Cournot using the downstream market demand function and treating the wholesale price as fixed. The resulting quantity supplied to the market is expressed as a function of the wholesale price and defines the derived demand function for the upstream level. The upstream producer optimizes his profit using this derived demand function, which gives the wholesale price that can be used in downstream expressions to obtain the quantities and prices as a function of costs, number of firms, etc.

The basic building block of the modeling used in the majority of models is a Cournot market with n firms. Following much of the literature in this area (e.g., Golombek and Gjelsvik (1995); Golombek et al. (1998); Egging and Gabriel (2005); Gabriel and Smeers (2005); Nese and Straume (2005); Boots et al. (2004)), the market is characterized by a linear demand function

$$Q = a - bp \,, \qquad [1]$$

where Q is the quantity demanded, p is the price and a and b are parameters of the demand function. Each firm chooses a profit maximizing quantity treating the quantities supplied by other firms as given, i.e., firm i maximizes

$$\pi_i = q_i * (p - k_i) = q_i * (\frac{a - q_i - q_{-i}}{b} - k_i) \qquad [2]$$

with respect to q_i. In this expression q_{-i} denotes the quantity supplied by all other traders except for trader i and k_i denotes the unit (and also marginal cost) cost of firm i. Besides being computationally convenient, constant marginal costs can be justified empirically both on the downstream and the upstream level. On the upstream level, one can argue that even if the production function were not linear, the overall quantity consumed on the downstream market in the Czech Republic is such a minor share of the overall production of the upstream producer that the producer acts as if it were linear. On the downstream level, the costs consist of the commodity price charged by the upstream producer, who charges the same price for each unit consumed, the transmission and storage cost, which is also the same for all units consumed as a result of legislative requirements and regulation, and administrative (transaction) costs.[11]

Due to concavity of the profit functions [2] the first order conditions yield the optimal solution

$$\frac{d\Pi_i}{dq_i} = \frac{a - q_i - q_{-i}}{b} - k_i - \frac{q_i}{b} = 0 \text{ for } i = 1..n. \qquad [3]$$

The solution of this system of linear equations yields the total quantity supplied as

$$Q = \frac{n}{n+1}a - \frac{b}{n+1}\sum_i k_i\ . \qquad [4]$$

Having specified the basic building block, I now proceed with the specific models. The models are divided into two groups. In the first group captured in section 4.1. In particular, I study the response of the upstream producer to a change on the downstream market after liberalization. In the second group analyzed in section 4.2., I focus on storage and analyze three storage deregulation scenarios.

[11] I do not explicitly consider the "portfolio effect," however, I touch on this issue in the discussion of the results.

Summary Table: Structure of the Individual Models

Model	No. of downstream traders	Downstream market (liberalized / regulated)	Storage	Storage control	Storage price mode (regulated / unregulated)
1	1	regulated	No	-	-
1a	*n*	liberalized	No	-	-
2	1	regulated	Yes	Bundled monopoly	regulated*
2ab	*n*	liberalized	Yes	Bundled monopoly	unregulated
2as	*n*	liberalized	Yes	Separate monopoly	unregulated
2ar	*n*	liberalized	Yes	Bundled monopoly	regulated

* Storage price is regulated indirectly through the regulation of the end-user price.

** Note on the numbering of models: A number without any letters denotes a model of the market prior to liberalization. The letter "a" stands for "after" and labels models after liberalization (as in 1a, 2ab, etc.). The letter "b" denotes **b**undled unregulated storage monopoly (2ab), "s" denotes **s**eparate storage monopoly (in 2as), and "**r**" denotes regulated storage prices (in 2ar).

4.1 Response of the Upstream to Downstream Liberalization

The basic idea of liberalization is that, rather than having a regulated monopoly, several firms (ideally a very large number) serve the market and compete away the formerly regulated margin, rendering regulation moot. As more and more companies enter the market, the margin shrinks and the end-user price declines to the (constant) unit cost. Therefore, the end-user price after liberalization should equal the formerly regulated price minus the formerly regulated margin.

In this section I analyze what happens if there is an upstream monopoly and how this monopoly responds to the change in the market structure. In particular, I investigate whether the logic described in the previous paragraph still operates.

The first model (model 1) is the benchmark case prior to the liberalization of the market. The second model (model 1a) captures downstream competition after deregulation.

4.1.1 Model 1

- **regulated downstream monopoly**
- **upstream monopoly**

The following setup corresponds to the situation on the Czech natural gas market prior to liberalization. The economy consists of consumers characterized by [1], a single downstream supplier with regulated end-user price and a single upstream (monopolistic) producer with unregulated wholesale price. The downstream monopolist purchases goods from the upstream producer for an unregulated wholesale price. The downstream monopolist then sells the goods to the end-users for a regulated price p_e which is equal to

$$p_e = p_w + m + c \, , \qquad [5]$$

where

p_w is the wholesale unit price,

c is the unit cost (marginal cost) of the downstream supplier, and

m is the margin allowed by the regulator.[12]

The downstream supplier simply supplies the quantity equal to the demand at the given end-user price p_e, therefore no optimization is involved at the downstream level.

On the other hand at the upstream level the upstream monopolistic producer is able to set the wholesale price to maximize its profit. Therefore the producer maximizes

---

[12] Alternatively, instead of a constant, the margin may be defined as a function of the wholesale price. According to Peltzman (1976) a change in the wholesale price changes the total wealth to be redistributed by the regulator and the redistribution itself. When the regulator defines *m* as an increasing function of the wholesale price, the results (i.e., the magnitude of the difference between the wholesale prices in the regulated and liberalized scenario) are more pronounced. On the other hand, when *m* is a decreasing function of the wholesale price, which is a more realistic case as regulators sometimes refuse to pass on cost increases to consumers (or spread the cost increase over a longer time period), the results are less pronounced. For steeply decreasing functions *m,* for which $m(p_w) > m'(p_w)[p_w - s]$, the results do not hold. However, when the regulated margin is a steeply decreasing function of the wholesale price, the regulator shifts profits from the domestic monopoly to the upstream monopolistic producer who is motivated by the decreasing domestic margin to increase the wholesale price, which clearly should not be the objective of the domestic regulator.

$$\max_{p_w^r} \{Q(p_e)*(p_w - s)\}, \qquad [6]$$

where

Q is the domestic demand function, and

s is the producer's unit cost (marginal cost)

Therefore, the maximization problem using the demand function specification [1] is

$$\max_{p_w} \{[a - b(p_w + c + m)]*(p_w - s)\}. \qquad [7]$$

Since the objective function is concave, the optimal price and quantity can be computed from the first-order condition:

$$\frac{d\Pi}{dp_w} = -b(p_w - s) + a - b(p_w + c + m) = 0. \qquad [8]$$

The results are summarized in the following table:

Model 1 Summary Table

Variable	Expression
Wholesale price p_w^1	$p_w^1 = \frac{1}{2}(\frac{a}{b} + s - c - m)$
End-user price p_e^1	$p_e^1 = \frac{1}{2}(\frac{a}{b} + s + c + m)$
Total quantity sold Q^1	$Q^1 = \frac{1}{2}(a - b(s + c + m))$

4.1.2 Model 1a

- **liberalized downstream**
- **upstream monopoly**

Model 1a describes the natural gas industry after liberalization with a single upstream producer. Therefore the economy consists of a single upstream producer, *n* downstream suppliers and domestic end-users.

On the downstream level, *n* downstream suppliers compete in quantities which leads to the total quantity supplied characterized by [4]. Similarly to model 1, the upstream monopolist considers the downstream structure and optimizes its pricing strategy taking into account the quantity demanded by the downstream suppliers at different wholesale price levels. Therefore, using the outcome of Cournot competition [4] and the fact that the unit cost consists of the wholesale unit price p_w plus the traders' other unit costs c_i the upstream monopoly maximizes its profit

$$\max_{p_w}\left(\left(\frac{n}{n+1}a-\frac{n}{n+1}bp_w-\frac{b}{n+1}\sum_i c_i\right)*\left(p_w-s\right)\right). \qquad [9]$$

Since the objective (profit) function is concave, first order conditions may be used to obtain the optimal solution from the perspective of the upstream monopolist:

$$\frac{d\pi}{dp_w}=\frac{n}{n+1}a-\frac{n}{n+1}bp_w-\frac{b}{n+1}\sum_i c_i-\frac{n}{n+1}b\left(p_w-s\right)=0\,, \qquad [10]$$

which after simplification gives the expressions summarized in the following table.

Model 1a Summary Table

Variable	Expression
Wholesale price p_w^{1a}	$p_w^{1a} = \frac{1}{2}\left(\frac{a}{b} - \frac{\sum_i c_i}{n} + s\right)$
End-user price p_e^{1a}	$p_e^{1a} = \frac{1}{2}\left(\frac{a}{b} * \frac{n+2}{n+1} + \frac{sn}{n+1} + \frac{\sum_{i=1}^{n} c_i}{n+1}\right)$
Total quantity sold Q^{1a}	$Q^{1a} = \frac{n(a-bs)}{2(n+1)} - \frac{b\sum_{i=1}^{n} c_i}{2(n+1)}$
Price differential $\Delta p_e^{1,1a}$	$\Delta p_e^{1,1a} = \frac{1}{2}\left[\frac{a}{b(n+1)} - \frac{s}{n+1} + \frac{\sum_{i=1}^{n} c_i}{n+1} - c - m\right]$

It is now interesting to see how the endogeneity of the wholesale price impacts market liberalization outcome. In particular, if all traders have the same unit cost (c), the wholesale price is

$$p_w^{1a} = \frac{1}{2}\left(\frac{a}{b} - c + s\right), \qquad [11]$$

which is higher, by 0.5 m, than the original wholesale price before liberalization. Therefore, by optimizing over the downstream structure, the upstream producer is capable of capturing one half of the price benefit brought about by liberalized downstream market regardless of the number of downstream traders. Moreover, this expression does not depend on the number of traders n, which means that the change in the pricing of the upstream producer does not require fully functioning liberalization with many traders. Instead, the wholesale price changes as soon as regulation is revoked and the current contracts expire.

Nevertheless, even if the wholesale price increases, consumers may still benefit from the deregulation. Perfect competition yields the end-user price

$$p_e^{1a,comp} = \frac{1}{2}\left(\frac{a}{b} + s + c\right), \qquad [12]$$

which is 0.5 m lower than the price under regulation, i.e., the original margin is split equally between consumers and the upstream producer.

Comparison of models 1 and 1a

Variable	Model 1	Model 1a
Wholesale price p_w	$p_w^1 = \frac{1}{2}(\frac{a}{b} + s - c - m)$	$p_w^{1a} = \frac{1}{2}\left(\frac{a}{b} - \frac{\sum_i c_i}{n} + s\right)$
End-user price p_e	$p_e^1 = \frac{1}{2}(\frac{a}{b} + s + c + m)$	$p_e^{1a} = \frac{1}{2}\left(\frac{a}{b} * \frac{n+2}{n+1} + \frac{sn}{n+1} + \frac{\sum_{i=1}^{n} c_i}{n+1}\right)$
Total quantity sold Q	$Q^1 = \frac{1}{2}(a - b(s + c + m))$	$Q^{1a} = \frac{n(a - bs)}{2(n+1)} - \frac{b\sum_{i=1}^{n} c_i}{2(n+1)}$
End-user price p_e^{comp} under perfect competition		$p_e^{1a,comp} = \frac{1}{2}\left(\frac{a}{b} + s + c\right)$

4.2 Natural Gas Storage

A very important aspect of the natural gas sector, which distinguishes it, e.g., from the electricity industry, is the possibility to store natural gas (usually in underground storage facilities). Due to this feature it is possible to uniformly use the full capacity of transit pipelines all year round regardless of the seasonal fluctuations in the downstream demand for gas (provided that storage is close to the place of consumption).[13]

In the following section I incorporate storage into the preceding models of the natural gas market but for the sake of calculation I simplify the structure as follows: Instead of considering a (possibly different) demand schedule[14] for each firm, I split the gas year into high season (winter) and low season (summer) and consider a fixed ratio of consumption in high and low seasons, denoted by γ. This abstraction is in fact not that far from the reality. Although the consumption curve of each firm is necessary for correctly supplying the right amount of gas each day (and in fact each hour), from the perspective of working gas storage capacity and the determination of prices of storage capacity, all that is necessary is the amount of gas that will be injected into the storage facility in the low season and consequently extracted from the storage facility in the high season, i.e., the certain volume of capacity needed to accommodate the consumer. Moreover, the assumption that the seasonal consumption ratio γ is the same throughout the economy does not necessarily mean that all firms have the same consumption profile but rather that all traders have the same mix of customers. Using equations to capture these features, a trader supplying quantity q_i to the market will deliver $q_{Hi} = \gamma q_i$ in the high season and $q_{Li} = (1-\gamma)q_i$ in the low season where $\gamma \geq 0.5$. Therefore, if the supply of gas from producers to traders is uniform over the seasons and equal to $\frac{q_i}{2}$, in

---

[13] In fact foreign gas supply through long-distance transit pipelines is usually not absolutely uniform throughout the year as producers usually offer contracts with a certain band for fluctuations (e.g., +/-20%). However, this bandwidth is far from sufficient to cover the difference between winter and summer consumption. In the analysis below I abstract from this option since the only difference for my investigation would be lower demand for storage capacity, i.e. lower parameter γ, which is in the case of closed form solutions without numerical results irrelevant.

[14] Instead of a simple demand curve $D : p \to q$, consumers are best characterized by a demand function which transforms the price of natural gas p to a function which captures the demanded consumption for each day of the year.

the low season it is necessary to accumulate a volume of gas equal to the difference between the volume actually delivered through gas pipelines from the producer and the volume demanded in the high season, i.e.

$$q_{Si} = \gamma q_i - \frac{q_i}{2} = q_i\left(\gamma - \frac{1}{2}\right), \qquad [13]$$

which is also the required storage capacity for the given year. Having specified the basic principles of natural gas storage and seasonal consumption, it is now possible to elaborate models of the whole economy taking into account the market structure. In all models below I use the approach reflected in models 1 and 1a (i.e., endogenous wholesale price), where upstream traders react to the change in the downstream structure, which is exactly what every profit driven firm should do.

I start with the benchmark model 2 prior to liberalization and then I look at three possible market development scenarios: In model 2ab, storage is unregulated and controlled by the incumbent; in model 2as, storage is owned by a separate entity and unregulated; and in model 2ar, storage is controlled by the incumbent, however, the storage price is regulated.

4.2.1 Model 2

- **regulated downstream monopoly also owns all storage facilities**
- **upstream monopoly**

Model 2 captures the situation on the Czech natural gas market prior to liberalization. The downstream segment consists of a single regulated monopolist who also owns all storage facilities. Denoting the unit cost (constant marginal cost) of storage capacity as c_s, the end-user price is

$$p_e = p_w + m + c + s_s\left(\gamma - \frac{1}{2}\right). \qquad [14]$$

Using $c + s_s\left(\gamma - \frac{1}{2}\right)$ instead of c in all results of model 1 gives the results summarized in the following table.

Model 2 Summary Table

Variable	Expression
Wholesale price p_w^2	$p_w^2 = \frac{1}{2}(\frac{a}{b} + s - c - s_s\left(\gamma - \frac{1}{2}\right) - m)$
End-user price p_e^2	$p_e^2 = \frac{1}{2}(\frac{a}{b} + s + c + s_s\left(\gamma - \frac{1}{2}\right) + m)$
Total quantity sold Q^2	$Q^2 = \frac{1}{2}(a - b(s + c + s_s\left(\gamma - \frac{1}{2}\right) + m))$

4.2.2 Model 2ab

- **liberalized downstream**
- **storage controlled by incumbent**
- **upstream monopoly**

In this model I assume that one of the downstream traders, the incumbent, controls the storage capacity. This model is an extreme interpretation of the situation on the Czech natural gas market where the former regulated monopoly controls all domestic storage facilities.[15] In reality, the regulatory authorities do have some tools to control storage; nevertheless, it is interesting to see what happens if storage is left unregulated.

Intuitively, such a setup enables the incumbent to keep other traders from entering the market. The following section analyzes this problem.

The profit of the incumbent (trader/storage operator denoted no. 1) is

[15] In the Czech Republic there are 8 underground gas storage facilities of which 6 are owned by RWE Transgas, one is leased to RWE Transgas and one is used solely for the needs of the Slovak gas system.

$$\pi_1 = q_1\left(\frac{a-q_1-q_{-1}}{b} - p_w - c\right) - q_1 s_s\left(\gamma - \frac{1}{2}\right) + q_{-1}\left(\gamma - \frac{1}{2}\right)(p_s - s_s), \qquad [15]$$

which is the highest when the quantity supplied by other traders is zero. In order to achieve this, the trader/storage operator sets the storage prices to a sufficiently high level to drive away all competing traders and behaves as a monopoly on the whole market, i.e., sets the storage price so that the unit cost of each trader (which includes the artificially exaggerated storage price) is higher than the monopoly end-user price.[16]

The profit maximizing quantity of a downstream monopolist is

$$q_1 = \frac{1}{2}\left(a - bp_w - bc - b\left(\gamma - \frac{1}{2}\right)s_s\right) = Q. \qquad [16]$$

This result can be used for the analysis of the behavior of the upstream producer. Since both the downstream trader/storage operator and the upstream producer are monopolists on their segments, the overall economy has a structure of a successive monopoly. This structure was investigated by Spengler [1950] and further developed by e.g., Tirole (1988) (pp. 169-198) and is now known as double marginalization. Under this structure both monopolists successively exercise their monopolistic powers, which results in a situation that is worse for the consumers (higher prices and lower quantity supplied) than in the case of a vertically integrated monopolist.

The upstream producer optimizes his profit

$$\Pi = Q*(p_w - s) = \frac{1}{2}\left(a - bp_w - bc - b\left(\gamma - \frac{1}{2}\right)s_s\right)*(p_w - s), \qquad [17]$$

which gives the results summarized in the table below.

[16] The condition is $\left(\gamma - \frac{1}{2}\right)p_s + p_w + c > p_e$.

Model 2ab Summary Table

Variable	Expression
Wholesale price p_w^{2ab}	$p_w^{2ab} = \frac{1}{2}\left(\frac{a}{b} - c - \left(\gamma - \frac{1}{2}\right)s_s + s\right)$
End-user price p_e^{2ab}	$p_e^{2ab} = \frac{1}{4}\left(\frac{3a}{b} + s + c + \left(\gamma - \frac{1}{2}\right)s_s\right)$
Total quantity sold Q^{2ab}	$Q^{2ab} = \frac{1}{4}\left(a - bs - bc - b\left(\gamma - \frac{1}{2}\right)s_s\right)$

The results of this model are not surprising: by controlling the storage facilities, an essential input in the supply of gas to end-users, the bundled trader and storage operator is capable of using its monopolistic power on the downstream segment and exploiting the market. However, the extent to which this model currently applies to Czech natural gas is questionable – see the discussion of the results.

4.2.3 Model 2as

- **liberalized downstream**
- **storage owned by separate monopoly**
- **upstream monopoly**

In this model the downstream segment consist of traders who purchase natural gas from the upstream monopolistic producer and storage services (storage capacity) from a separate monopolistic storage operator. This setup does not reflect the actual situation on the Czech market since Czech storage facilities are currently controlled by the incumbent. However, it is one of the possible scenarios of further development and is therefore here. In fact, it is a very relevant scenario as ownership unbundling is advocated by the EU as a liberalization-promoting measure.

Since the unit storage cost (in the sense of cost of storage per unit of gas supplied, not the cost of unit of gas stored) for downstream traders is

$$c_s = \left(\gamma - \frac{1}{2}\right) * p_s, \qquad [18]$$

where p_s is the storage price charged by the storage operator, and the profit of downstream trader i is

$$\pi_i = q_i\left(\frac{a - q_i - q_{-i}}{b} - p_w - c - \left(\gamma - \frac{1}{2}\right)p_s\right). \quad [19]$$

Due to the concavity of the profit with respect to the quantity supplied, the optimal solution and the total quantity supplied can again be computed from the first-order conditions:

$$Q = \frac{n}{n+1}a - \frac{n}{n+1}bp_w - \frac{b}{n+1}\sum_i c_i - \frac{n}{n+1}b\left(\gamma - \frac{1}{2}\right)p_s. \quad [20]$$

Thus the total storage capacity used is

$$Q_s = \left(\gamma - \frac{1}{2}\right)Q = \left(\gamma - \frac{1}{2}\right)*\left[\frac{n}{n+1}a - \frac{n}{n+1}bp_w - \frac{b}{n+1}\sum_i c_i - \frac{n}{n+1}b\left(\gamma - \frac{1}{2}\right)p_s\right]. \quad [21]$$

This can now be used to define the storage operator's problem as a simple profit maximization exercise where the objective profit function is

$$\pi_s = Q_s(p_s - s_s) = \left(\gamma - \frac{1}{2}\right)*\left[\frac{n}{n+1}a - \frac{n}{n+1}bp_w - \frac{b}{n+1}\sum_i c_i - \frac{n}{n+1}b\left(\gamma - \frac{1}{2}\right)p_s\right]*(p_s - s_s),$$

[22]

where s_s is the unit storage cost of the storage system operator. Due to the concavity of the objective function with respect to the storage price, first order conditions give the optimal solution:

$$\frac{d\pi_s}{dp_s} = \left(\gamma - \frac{1}{2}\right)*\left[\frac{n}{n+1}a - \frac{n}{n+1}bp_w - \frac{b}{n+1}\sum_i c_i - \frac{n}{n+1}b\left(\gamma - \frac{1}{2}\right)p_s\right] - \frac{n}{n+1}b\left(\gamma - \frac{1}{2}\right)^2 *(p_s - s_s) = 0\cdot$$

[23]

Solving for p_s gives

$$p_s = \frac{a - bp_w - \frac{b}{n}\sum_i c_i + b\left(\gamma - \frac{1}{2}\right) * s_s}{2b\left(\gamma - \frac{1}{2}\right)} . \qquad [24]$$

Now let's investigate the optimal behavior of the upstream producer given the downstream structure. Similarly as in model 1a, the upstream monopolistic producer maximizes his profit, which is defined as

$$\Pi = Q(p_w) * (p_w - s), \qquad [25]$$

which after substituting for the various components of Q gives

$$\Pi = \left[\frac{n}{2(n+1)}a - \frac{n}{2(n+1)}bp_w - \frac{b}{2(n+1)}\sum_i c_i - \frac{nb}{2(n+1)}\left(\gamma - \frac{1}{2}\right) * s_s\right] * (p_w - s) . \quad [26]$$

This function is again concave so FOC can be used to obtain the results.

Model 3as Summary Table

Variable	Expression
Wholesale price p_w^{2as}	$p_w^{2as} = \frac{1}{2}\left(\frac{a}{b} - \bar{c} - \left(\gamma - \frac{1}{2}\right)s_s + s\right)$
End-user price p_e^{2as}	$p_e^{2as} = \frac{1}{4}\frac{n}{n+1}\left(\frac{3n+4}{n}\frac{a}{b} + \bar{c} + \left(\gamma - \frac{1}{2}\right)s_s + s\right)$
Total quantity sold Q^{2as}	$Q^{2as} = \frac{1}{4}\frac{n}{n+1}\left(a - b\bar{c} - b\left(\gamma - \frac{1}{2}\right)s_s - bs\right)$

It is worth noting that the storage monopoly does not influence the wholesale price. The wholesale price of model 2as is similar to the wholesale price of model 2a, now only the storage cost is added to the trader's unit cost. Consequently, it is possible to observe the same development of the wholesale price after market liberalization as in models 1 and 1a, i.e., half of the original margin of the regulated monopoly is captured in an unregulated environment by the upstream producer due to which the wholesale price increases.

Where the monopolist structure of the storage matters is the downstream market. Let us therefore take a look at what happens as *n* gets large (the number of downstream traders increases). The end-user price in this case converges to the perfect competition outcome (that is perfect competition in trading, not perfect competition in storage services):

$$p_e^{2as,comp} = \frac{1}{4}\left(3\frac{a}{b} + \bar{c} + \left(\gamma - \frac{1}{2}\right)s_s + s\right). \qquad [27]$$

In comparison with model 1a, the end-user price is now driven more by the demand function than the actual costs.[17]

Moving to a comparison with model 2ab, notice that the results of model 2ab are identical with the results of model 2as under perfect competition and are better from the perspective of the consumers than in model 2as when perfect competition is not achieved (i.e., the end-user price is smaller). This might seem surprising at first glance; however, there is a straightforward explanation. While in model 2ab there is double marginalization, i.e., two monopolies successively charge a markup on the costs, in model 2as the markup is added on three levels. By splitting the bundled trader and storage operator, another level is created. Even though the lowest trading level is not monopolistic (there are *n* traders), unless there is perfect competition these traders charge prices above the unit costs which results in "triple marginalization." Similarly to vertical integration being preferred by end users over two successive monopolies (as shown, e.g., by Tirole (1988)), two successive monopolies are preferred over a configuration with three levels, of which two are monopolistic and the lowest one is

[17] In model 1a, the perfect competition price is $p_e^{1a,comp} = \frac{1}{2}\frac{a}{b} + \frac{1}{2}(\text{unit cost})$, whereas in model 2as, the perfect competition price is $p_e^{2as,comp} = \frac{3}{4}\frac{a}{b} + \frac{1}{4}(\text{unit cost})$. The first term of each equation $\frac{a}{b}$ is the limit price, i.e., price for which the quantity demanded is zero.

oligopolistic. In other words, although not optimal double marginalization is preferred over triple marginalization.

4.2.4 Model 2ar

- **liberalized downstream**
- **storage owned by the incumbent**
- **upstream monopoly**
- **regulator sets the storage price**

In this model I introduce a regulator (an analogue of the Czech Energy Regulatory Office) who has the power to set the price of storage services. This is the polar opposite of model 2ab (unregulated storage controlled by the incumbent). It reflects the fact that, although storage prices are currently not directly regulated, the Czech Energy Regulatory Office can regulate (and in fact until the beginning of 2007 did regulate) end-user prices and both the ERO and the Czech anti-monopoly office have the power to impose fines on the incumbent in cases when they discover that the incumbent has abused its dominant position.[18] Moreover, the EU directive 2003/55/EC concerning common rules for the internal market in natural gas requires negotiated or regulated access to storage, therefore storage regulation should be considered as one of the two feasible approaches.[19]

This model consists of an upstream monopoly and downstream (Cournot) competition with trader 1 being also the monopolistic storage operator with regulated prices of storage services. To solve the model I will follow the usual procedure starting with the profit optimization of downstream traders. The profit of trader 1 is

[18] On 26th May 2006, the ERO has imposed a fine of CZK 14.7 mil. on four gas companies from the RWE group for breaching the Act on Prices (ERO press release from May 2006). The proceedings were initiated after complaints of newly eligible customers concerning increasing gas prices in 2005. The Czech Office for the Protection of Competition (OPC, often referred to as anti-monopoly office) imposed a fine of CZK 370 mil. on RWE Transgas on 11th August 2006 for abusing its dominant position (although not yet enforced, the company has filed an appeal). One of the mentioned reasons for the penalty was that the price of storage services for eligible customers was too high (OPC press release August 2006).

[19] Regulated access to storage is used, e.g., in Italy, Belgium and Spain.

$$\pi_1 = q_1\left(\frac{a-q_1-q_{-1}}{b} - p_w - c\right) - q_1 s_s\left(\gamma - \frac{1}{2}\right) + q_{-1}\left(\gamma - \frac{1}{2}\right)(p_s - s_s), \qquad [28]$$

which is concave in the quantity supplied q_1. The profit of other traders is

$$\pi_i = q_i\left(\frac{a-q_i-q_{-i}}{b} - p_w - c - \left(\gamma - \frac{1}{2}\right)p_s\right) \text{ for } i = 2,..,n, \qquad [29]$$

which is also concave with respect to q_i. The maximum values of profit are thus derived from the first order conditions with respect to the quantities. These form a system of n linear equations which can be solved to obtain the quantities and prices. The resulting quantity supplied by trader 1 is

$$q_1 = \frac{a-bp_w}{n+1} + b\left(\gamma - \frac{1}{2}\right)\frac{(n-1)p_s}{n+1} - b\left(\gamma - \frac{1}{2}\right)\frac{ns_s}{n+1} + \frac{b}{n+1}\sum\nolimits_{i\neq 1} c_i - \frac{bc_1 n}{n+1}, \qquad [30]$$

while other traders supply

$$q_i = \left(a - b\left(p_w + c_i + \left(\gamma - \frac{1}{2}\right)p_s\right)\right) * \frac{n}{n+1} - \frac{1}{n+1}\sum\nolimits_{j\neq i,1}\left(a - b\left(p_w + c_j + \left(\gamma - \frac{1}{2}\right)p_s\right)\right) - \frac{1}{n+1}\left(a - b\left(p_w + c_1 + \left(\gamma - \frac{1}{2}\right)s_s\right)\right)$$
[31]

Adding up the quantities supplied by individual traders, I obtain the total quantity supplied as

$$Q = \frac{1}{n+1}\left[a - b\left(p_w + c_1 + \left(\gamma - \frac{1}{2}\right)s_s\right)\right] + \frac{1}{n+1}\sum\nolimits_{i\neq 1}\left[a - b\left(p_w + c_i + \left(\gamma - \frac{1}{2}\right)p_s\right)\right]. \qquad [32]$$

This quantity is now used by the upstream monopolist to maximize his profit. The profit function of the upstream monopoly is

$$\Pi = Q * (p_w - s) = \frac{1}{n+1}\left(na - nbp_w - bc_1 - b\left(\gamma - \frac{1}{2}\right)s_s - b\sum\nolimits_{i\neq 1} c_i - (n-1)b\left(\gamma - \frac{1}{2}\right)p_s\right)(p_w - s).$$
[33]

This function is concave in the wholesale price so the first order condition gives the maximum profit and the results are summarized in the following table.

Model 2ar Summary Table

Variable	Expression
Wholesale price p_w^{2ar}	$p_w^{2ar} = \frac{1}{2}\left(\frac{a}{b} - \bar{c} + s - \frac{\left(\gamma - \frac{1}{2}\right)s_s + (n-1)\left(\gamma - \frac{1}{2}\right)p_s}{n}\right)$
End-user price p_e^{2ar}	$p_e^{2ar} = \frac{1}{2(n+1)}\left((n+2)\frac{a}{b} + n\bar{c} + \left(\gamma - \frac{1}{2}\right)s_s + (n-1)\left(\gamma - \frac{1}{2}\right)p_s + ns\right)$
Total quantity sold Q^{2ar}	$Q^{2ar} = \frac{n}{2(n+1)}\left(a - b\bar{c} - b\frac{\left(\gamma - \frac{1}{2}\right)s_s + (n-1)\left(\gamma - \frac{1}{2}\right)p_s}{n} - bs\right)$
Price differential $\Delta p_e^{2,2ar}$	$\Delta p_e^{2,2ar} = \frac{1}{2b}\left[\frac{1}{n+1}a - \frac{1}{n+1}s - \frac{n}{n+1}c_1 - \frac{n}{n+1}b\left(\gamma - \frac{1}{2}\right)s_s + \frac{1}{n+1}b\sum_{i\neq 1}c_i + \frac{n-1}{n+1}b\left(\gamma - \frac{1}{2}\right)p_s - bm\right]$
End-user price under perfect competition $p_e^{2ar,comp}$	$p_e^{2ar,comp} = \frac{1}{2}\left(\frac{a}{b} + \bar{c} + \left(\gamma - \frac{1}{2}\right)p_s + s\right)$

The expression for the wholesale price is very similar to previous models, in particular models 2ab and 2as. The main difference is that the average unit cost is not constant, i.e., it depends on the number of traders. Provided that the storage price is higher than the storage cost, the average unit cost is increasing in the number of traders *n* due to which the wholesale price is decreasing in *n*. As for the comparison with the regulated case of model 2, the results are not as straightforward as in the previous models. If the storage price margin is high, it might even happen that the wholesale price will decline after liberalization. On the other hand, high storage price margin has a detrimental effect on the end-user price as it increases the average unit cost. Examining the effect of an extra downstream trader on the end-user price

$$p_e^n - p_e^{n+1} = \frac{1}{2(n+1)(n+2)}\left[\left(\frac{a}{b} - \left(\bar{c} + s - \left(\gamma - \frac{1}{2}\right)p_s\right)\right) - \left(\gamma - \frac{1}{2}\right)(p_s - s_s)\right], \qquad [34]$$

it might even happen that increased competition in combination with high storage prices will lead to higher end-user prices, i.e., the increase in average unit cost prevails over the benefits brought by a higher number of traders. This can be seen from equation [34] where the first part is positive (the limit price minus the total unit cost of trader $i > 1$), whereas the second part, the negative value of the storage price margin, is negative. Nevertheless, if the storage price is set “reasonably,” liberalization leads to lower end-user prices and higher wholesale prices.

It is worth noting that these results are interior solution results; if the storage price margin is too high, it might turn out to be optimal for trader 1 to supply the whole market at a price below the cost price of the other traders (i.e., if the monopoly price is below the unit cost of other traders).

Comparison of models 2, 2ab, 2as, 2ar

Variable	Model 2	Model 2ab	Model 2as	Model 2ar
Wholesale price p_w	$\frac{1}{2}(\frac{a}{b}+s-c-s_s\left(\gamma-\frac{1}{2}\right)-m)$	$\frac{1}{2}\left(\frac{a}{b}-c-\left(\gamma-\frac{1}{2}\right)s_s+s\right)$	$\frac{1}{2}\left(\frac{a}{b}-\bar{c}-\left(\gamma-\frac{1}{2}\right)s_s+s\right)$	$\frac{1}{2}\left(\frac{a}{b}-\bar{c}-\frac{\left(\gamma-\frac{1}{2}\right)(s_s+(n-1)p_s)}{n}+s\right)$
End-user price p_e	$\frac{1}{2}(\frac{a}{b}+s+c+s_s\left(\gamma-\frac{1}{2}\right)+m)$	$\frac{1}{4}\left(\frac{3a}{b}+s+c+\left(\gamma-\frac{1}{2}\right)s_s\right)$	$\frac{1}{4}\frac{n}{n+1}\left(\frac{3n+4}{n}\frac{a}{b}+\bar{c}+\left(\gamma-\frac{1}{2}\right)s_s+s\right)$	$\frac{n}{2(n+1)}\left(\frac{2n+1}{n}\frac{a}{b}+\bar{c}+\frac{\left(\gamma-\frac{1}{2}\right)(s_s+(n-1)p_s)}{n}+s\right)$
Total quantity sold Q	$\frac{1}{2}(a-b(s+c+s_s\left(\gamma-\frac{1}{2}\right)+m))$	$\frac{1}{4}\left(a-bs-bc-b\left(\gamma-\frac{1}{2}\right)s_s\right)$	$\frac{1}{4}\frac{n}{n+1}\left(a-b\bar{c}-b\left(\gamma-\frac{1}{2}\right)s_s-bs\right)$	$\frac{n}{2(n+1)}\left(a-b\bar{c}-\frac{b\left(\gamma-\frac{1}{2}\right)(s_s+(n-1)p_s)}{n}-bs\right)$
End-user price p_e^{comp} under perfect competition			$\frac{1}{4}\left(3\frac{a}{b}+\bar{c}+\left(\gamma-\frac{1}{2}\right)s_s+s\right)$	$\frac{1}{2}\left(\frac{a}{b}+\bar{c}+\left(\gamma-\frac{1}{2}\right)p_s+s\right)$

5 Discussion of the Results

The models above pointed out some problems associated with the liberalization of the Czech natural gas market.

Models 1 and 1a outlined one of the principal problems of the liberalization efforts: in an environment with a single upstream supplier, the wholesale price is not invariant to the changes in the downstream market structure. Considering the organization of the downstream market, in particular the withdrawal of end-user price regulation, the upstream monopoly is capable of capturing one half of the originally regulated margin, i.e., the upstream monopoly increases the wholesale price offered to downstream traders (for further implications of this result see below). Interestingly, the upstream producer does so regardless of the number of downstream traders, provided that the average unit cost does not change with the number of traders. Despite the increasing wholesale price, a sufficient number of traders is capable of pushing the price below the formerly regulated price level thus increasing consumer surplus.[20]

In model 2, I introduced storage as a necessary input for the supply of gas to end-users. If I were to consider storage as an input supplied competitively at an exogenous price, the results from models 1 and 1a would not change. However, the difference rests in the scarcity of this input and the control of its production facilities. While in model 2 there is no explicit storage price charged as storage facilities are owned by the monopolistic trader, two different scenarios are presented in models 2ab and 2as: in model 2ab storage is controlled by the incumbent trader and in model 2as the storage operator is a separate storage monopoly.

Model 2ab, whose storage structure is one extreme interpretation of the reality, yields results which were quite expected. The bundled trader and storage operator charges excessively high storage prices to prohibit other traders from entering the market. The response of the Energy Regulatory Office to the sharp increase in end-user prices after the first step of market liberalization and to the non-emergence of

[20] The theoretical calculations in this paper do not provide a concrete indication of what a "sufficient number" means. However, due to the change in the pricing of the upstream producer this number is higher than the number of traders required in the case of an exogenous price (e.g., in case of perfect competition on the upstream level).

competition suggests that this model is (or at least was) not completely irrelevant for the Czech Republic as it provides a rationalization of the fines imposed on the incumbent for abusing his dominant position. However, no clear straightforward conclusion can be drawn on this topic, as there are potential confounds to this explanation. In its press releases, the incumbent naturally denied the accusations of charging excessively high prices, stating that prices had risen only because of rising prices of natural gas substitutes (oils) and the price formula in contracts with foreign gas producers includes a component reflecting the market price of oil.[21]

One straightforward and at first glance viable solution to the problem of bundled storage control is the full ownership unbundling of the incumbent, which is captured in model 2as. In this model there is a separate storage owner. However, since this separate storage operator is a monopoly in storage services, the final outcome is even worse than in the bundled case of model 2ab. Instead of double marginalization presented in the bundled model, the unbundled model exhibits triple marginalization, i.e., markups are successively added by domestic traders, the separate storage monopoly and the upstream producer. Only if perfect downstream competition is achieved are the results identical with the results of the bundled model 2ab. This shows that in the case of storage monopoly the unbundling of storage services, even though it ensures equity among individual traders, is from the perspective of the end-user inferior to the regulated model 2 as well as the bundled model 2ab with a single domestic monopolistic trader. This result contradicts the results of Van Koten (2006), who, in a different setting, in which (partially) vertically integrated auctioneer and bidder participate in electricity transmission capacity auction, concludes that vertical integration or incomplete unbundling is from the perspective of welfare inferior to

[21] The average monthly price of Brent oil increased from USD 44.23 per barrel in January to USD 64.12 per barrel in August, i.e., by almost 50 % (Source: International Energy Agency).
There are two more reasons which support the opinion that the complaints are exaggerated and which might have contributed to the difference in the increase of prices for captive and eligible customers. One reason is that the price for captive customers was regulated and is adjusted on a quarterly basis as a result of which its development lags behind the market price development. ERO was thus capable of buffering the effect of rising commodity prices by spreading the price increase into several periods. The second reason why the difference between the increase in prices for captive and eligible customers seems so high (17-19 % vs. 30-40%) is the fact that the commodity component of the final price is greater for large-volume customers than for households. Therefore, the same increase in commodity price will lead to smaller overall percentage increase in prices for households.

complete ownership unbundling. This difference in conclusions is due to the differences in the structures of the analyzed problems, in particular due to the fact that my analysis treats the storage operator as a Stackelberg leader who is able to optimize over the downstream, whereas in Van Koten's work, the seller markets the capacity using auctions and thus his powers are relatively weaker.

As one of the two options of the second EU gas directive (55/2006/EC), I introduce regulation of access to storage to the analyzed models. This is done in model 2ar where the extending assumption is that storage price is set by the regulator. When examining this model it turns out that contrary to model 1a, the wholesale price is no longer independent of the number of downstream traders. This is due to the asymmetricity in the storage costs: while trader 1 (bundled trader and storage operator) pays only the direct storage cost, other traders pay the regulated storage price. The wholesale price can be expressed as

$$p_w^{3ar} = \frac{1}{2}\left(\frac{a}{b} - \bar{c} + s - \left(\gamma - \frac{1}{2}\right)s_s\right) - \frac{1}{2}\frac{n-1}{n}\left(\gamma - \frac{1}{2}\right)m_s, \qquad [35]$$

where m_s is the regulated storage price margin. In comparison with model 1a, the second component is new. A similar expression may be obtained for the end-user price:

$$p_e^{3ar} = \frac{1}{2(n+1)}\left((n+2)\frac{a}{b} + n\bar{c} + n\left(\gamma - \frac{1}{2}\right)s_s + (n-1)\left(\gamma - \frac{1}{2}\right)m_s + ns\right). \qquad [36]$$

Notice that the wholesale price is decreasing and the end-user price is increasing in the storage price margin. This has a serious impact for the economy. If the margin is set low or even negative so as to promote competition and favor new traders over the incumbent, the wholesale price charged by the upstream producer increases, and in the case of a negative storage price margin even exceeds the wholesale price of model 1a. On the other hand, the high regulated storage margin increases the end-user price and favors the incumbent, which is clearly not the desired effect of market liberalization.

Nevertheless, if the storage margin is not too high in comparison with the formerly regulated monopoly margin, i.e., if

$$\frac{n-1}{n}\left(\gamma-\frac{1}{2}\right)m_s < m\,, \qquad [37]$$

the wholesale price after liberalization increases similarly to models 1 and 1a. The violation of this inequality would mean that the regulator allows the storage operator to earn such a high margin on storage that the end-user price under perfect competition is higher than the end-user price in the case of regulated model 2, i.e.

$$\frac{1}{2}\left(\frac{a}{b}+\bar{c}+\left(\gamma-\frac{1}{2}\right)s_s+\left(\gamma-\frac{1}{2}\right)m_s+s\right)>\frac{1}{2}\left(\frac{a}{b}+\bar{c}+\left(\gamma-\frac{1}{2}\right)s_s+m+s\right). \qquad [38]$$

This is clearly not the desired outcome of liberalization and will not be supported in the long-term.

One more important observation drawn from this model concerns the timing of the change in the pricing strategy of the upstream producer. Similarly to model 1a, the upstream producer does not change the pricing strategy only after new traders enter the downstream market. The upstream producer adjusts the pricing strategy immediately after both regulation is withdrawn and contracts concluded before liberalization expire, even if the downstream market is served only by the incumbent. In such case the magnitude of the wholesale price increase is, similarly to models without storage, one half of the previously regulated end-user price margin.

The regulated/liberalized model pairs 1+1a and 2+2ar consistently show the following two main results:

1) liberalization can achieve lower end-user prices if the number of traders is sufficiently high;

2) the upstream captures some of the benefits of liberalization by changing its pricing strategy and increasing the wholesale price.

Considering the first result, it might be very difficult to achieve a sufficiently high number of competitors even when all traders have the same conditions. One reason is the fact that larger gas traders benefit from the portfolio effect, i.e., the fact that the aggregated demand of many customers is smoother and more stable than the demand of a single customer and coping with demand fluctuations is costly. The significance of this reason even increases in light of the second result: in comparison with the standard liberalization setup, when changes in the wholesale price are not considered (i.e., the whole formerly regulated margin is competed away by entrants), the minimum efficient number of traders is higher[22] when the upstream producer responds to the market change.

As for the second main result, it hints at why it might be difficult to reach the liberalized competitive state. It shows that storage and the potential for abusing the dominant position, as examined in model 2ab, are not the only reasons why there are no new entrants emerging. The non-emergence of new traders might be partly caused by the fact that upstream producers, expecting a competitive liberalized outcome, adapt their pricing strategies to the new conditions thus charging a higher wholesale price to new traders. In turn, the entrants cannot compete with the incumbent to whom the upstream producers supply gas for a price, which has been set some time before liberalization and which cannot change until the long-term supply contracts between the incumbent and the producers expire.

6 Conclusion

I have used successive oligopoly models to analyze the Czech natural gas market with a special focus on the impact of the response of the upstream producer to market liberalization and on the organization of storage. The comparisons of the benchmark pre-liberalization models with liberalized scenarios uncover obstacles on the path to

---

[22] It can be shown that the minimum efficient number of traders, defined as the minimum number of traders required to push the end-user price below the end-user price in the regulated pre-liberalization scenario, is in the case of endogenous wholesale price higher than in the case of an exogenous wholesale price by $\Delta n = \frac{m_w^0}{m}$, where m is the formerly regulated margin of the incumbent and m_w^0 is the profit margin of the upstream producer before market liberalization.

efficient liberalization. One of the main results of the investigation is that, although a sufficiently high number of competitors may ultimately drive the price down below the pre-liberalization level sometime in the future, the outcome is hindered by the fact that upstream producers are capable of capturing a significant share of the formerly regulated price margin. This change in the price, coupled with the existence of long-term supply contracts concluded by the established players under the old pricing strategy, prevents new traders from reaching to competitive gas supply and thus entering the market. As for the storage structure, from the perspective of the consumer, regulated storage outperforms both bundled and even more significantly unbundled storage monopoly. In light of these results ownership unbundling of storage to a single company should definitely be rejected as the worst alternative from the perspective of consumer welfare.

References

Act no. 458/2000 Coll., on business conditions and public administration in the energy sectors and on amendments to other laws (the “Energy Act”), available at http://www.eru.cz/frameset_aj.htm.

Clement, Emmanuel; Goerten, John: *Competition indicators in the gas market of the European Union*, Manuscript of the European Communities, 2005 http://epp.eurostat.cec.eu.int/portal/page?_pageid=1073,46587259&_dad=portal&_schema=PORTAL&p_product_code=KS-NQ-05-008.

Boots, Maroeska G., Rijkers, Fieke A.M., Hobbs, Benjamin: *Modelling the Role of Trading Companies in the Downstream European Gas Market: A Successive Oligopoly Approach*, *The Energy Journal*, Vol. 25, Issue 3, 2004, pp. 73-102.

Boots, Maroeska G., Rijkers, Fieke A.M., Hobbs, Benjamin: *GASTALE: An oligopolistic model of production and trade in the European gas market*, ECN Policy Studies Report ECN-R—03-001, 2003.

Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in electricity and repealing Directive 96/92/EC, http://europa.eu.int/comm/energy/electricity/legislation/legislation_en.htm.

Directive 2003/55/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in natural gas and repealing Directive 98/30/EC, http://europa.eu.int/comm/energy/gas/legislation/legislation_en.htm.

Egging, Rudolf G., Gabriel, Steven A.: *Examining market power in the European gas market*, Energy Policy, Volume 34, Issue 17 Nov. 2006, pp. 2762-2778.

Energy Regulatory Office of the Czech Republic: *Decree No. 524/2006 concerning the rules for the organisation of the gas market and the creation and use of gas supply type diagrams*, available at http://www.eru.cz/.

Energy Regulatory Office of the Czech Republic: *Decree No. 673/2004 laying down the rules for the organisation of the gas market as amended by Decree No. 542/2005*, available at http://www.eru.cz/.

Energy Regulatory Office of the Czech Republic: *Press release concerning the fines imposed on gas companies from 26th May 2006*, available in Czech at http://www.eru.cz/doc/tisk_2006_05_26.doc.

Energy Regulatory Office of the Czech Republic: *Press release from 14th October 2005*, available at http://www.eru.cz/frameset_aj.htm.

Energy Regulatory Office of the Czech Republic: *Price decisions and prices and tariffs 1996-2005*, http://www.eru.cz.

Energy Regulatory Office of the Czech Republic: *Report on the approach to setting the key parameters of the regulatory formula and prices for the second regulatory period in the gas industry*, May 2005, available at http://www.eru.cz/frameset_aj.htm.

European Commission: *Green Paper - Towards a European Strategy for the Security of Energy Supply*, Luxembourg: Office for Official Publications of the European Communities, 2001 http://europa.eu.int/comm/energy_transport/en/lpi_en.html.

Gabriel, Steven, Smeers, Yves: *Complementarity problems in restructured natural gas markets*, Center for Operations Research and Econometrics (CORE) discussion paper 2005/37.

Golombek, Rolf; Gjelsvik, Eystein: *Effects of liberalizing the natural gas markets in Western Europe*, The Energy Journal, Volume 16, no. 1, 1995.

Golombek, Rolf; Gjelsvik, Eystein; Rosendahl, Knut Einar: *Increased Competition on the Supply Side of the Western European Natural Gas Market*, The Energy Journal, Volume 19, no. 3, 1998.

Greenhut, M.L., Ohta, H.: *Vertical Integration of Successive Oligopolists*, The American Economic Review, Vol. 69, No. 1 March 1979, pp. 137-141.

Holz, Franziska, Kalashnikov, Vitaly: *A Strategic Model of European Gas Supply*, a paper presented at the spring meeting of young economists, April 22-24 2005, Geneva

Kreps, David M., Scheinkman, José A.: *Quantity precommitment and Bertrand competition yield Cournot outcomes*, The Bell Journal of Economics, Vol. 14, No. 2, 1983, pp. 326-337.

Kubátová, Zuzana: *Vemex chce nabídnou levnější plyn (Vemex wants to offer cheaper gas)*, ihned news server http://ihned.cz/3-22921635-vemex-000000_d-16, 6th April 2006.

Ministry of Foreign Affairs of the Czech Republic: *Dovoz zemního plynu z Norska (Import of natural gas from Norway)*, information from 16th January 2006 available at the CzechTrade information server at http://www.businessinfo.cz/cz/clanky/norsko/dovoz-zemniho-plynu-z-norska/1000790/38636/.

Ministry of Foreign Affairs of the Czech Republic: *Export zemního plynu z Norska (Export of natural gas from Norway)*, information from 3rd February 2006 available at the CzechTrade information server at http://www.businessinfo.cz/cz/clanky/norsko/export-zemniho-plynu-z-norska/1000790/38983/.

Ministry of Industry and Trade: *National Report of the Czech Republic about the Electricity and Gas Sector for the Year 2005,* http://www.mpo.cz/dokument21520.html, August 2006.

Ministry of Industry and Trade: *National Report of the Czech Republic about the Electricity and Gas Sector for the Year 2006,* http://www.mpo.cz/dokument34335.html , September 2007.

Mravec, Michal: *Understanding the Failure (so far) of the Liberalization of the Czech Market in Natural Gas: Some Models*, CERGE-EI discussion paper no. 169, 2006.

Nese, Gjermund, Straume, Odd Rune: *Industry concentration and strategic trade policy in successive oligopoly*, CESifo working paper no. 1439, 2005.

Office for the Protection of Competition of the Czech Republic: Press Release - Record fine of 370 million was imposed upon RWE Transgas, 11th August 2006, http://www.compet.cz/en/competition/news-competition/article/2006/08/record-fine-of-370-million-was-imposed-upon-rwe-trangas/.

Peltzman, Sam: *Toward a More General Theory of Regulation*, Journal of Law and Economics, Vol. 19, No. 2, 1976, pp. 211-240.

RWE Transgas, a.s.: *Annual Report 2004*, http://www.rwe-transgas.cz/transgas.en/press_centre/history_annual/zprava_2004.pdf, 2004.

RWE Transgas, a.s.: *Annual Report 2005*, http://www.rwe-transgas.cz/transgas.en/press_centre/annual_report/vyrocni-zprava-2005-en.pdf, 2005.

Shy, Oz: *Industrial Organization: Theory and Applications*, MIT Press, Cambridge, Massachusetts 1995.

Spengler, J.: *Vertical Integration and Anti-trust Policy*, Journal of Political Economy 58, 1950, pp. 347-352.

Tirole, Jean: *The Theory of Industrial Organization*, MIT Press, Cambridge, Massachusetts 1988.

Van Koten, Silvester: *Bidding behavior when one bidder and the auctioneer are vertically integrated: Implications for the partial deregulation of EU Electricity markets*, CERGE-EI working paper no. 313, http://www.cerge.cuni.cz/publications/working_papers, 2006.

Individual researchers, as well as the on-line and printed versions of the CERGE-EI Working Papers (including their dissemination) were supported from the following institutional grants:

- Center of Advanced Political Economy Research [Centrum pro pokročilá politicko-ekonomická studia], No. LC542, (2005-2009),
- Economic Aspects of EU and EMU Entry [Ekonomické aspekty vstupu do Evropské unie a Evropské měnové unie], No. AVOZ70850503, (2005-2010);
- Economic Impact of European Integration on the Czech Republic [Ekonomické dopady evropské integrace na ČR], No. MSM0021620846, (2005-2011);

Specific research support and/or other grants the researchers/publications benefited from are acknowledged at the beginning of the Paper.

Published by
Charles University in Prague, Center for Economic Research and Graduate Education (CERGE)
and
Economics Institute ASCR, v. v. i. (EI)
CERGE-EI, Politických vězňů 7, 111 21 Prague 1, tel.: +420 224 005 153, Czech Republic.
Printed by CERGE-EI, Prague
Subscription: CERGE-EI homepage: http://www.cerge-ei.cz

Editors: Directors of CERGE and EI
Managing editors: Deputy Directors for Research of CERGE and EI

ISSN 1211-3298
ISBN 978-80-7343-141-9 (Univerzita Karlova. Centrum pro ekonomický výzkum a doktorské studium)
ISBN 978-80-7344-130-2 (Národohospodářský ústav AV ČR, v. v. i.)

CERGE-EI
P.O.BOX 882
Politických vězňů 7
111 21 Praha 1
Czech Republic
http://www.cerge-ei.cz