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**Working Paper**

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# Main drivers of natural gas prices in the Czech Republic: Market reform vs. long-term contracts

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## **Abstract:**

One of the goals of the European Commission in the energy sector is creating a single competitive European market. The decision of the European Union to liberalise energy markets has far-reaching consequences not only for gas companies, but also for the rest of the real economy in view of the fact that natural gas is being used as a primary energy source.

In this paper we aim to answer how liberalisation has influenced gas pricing/prices in the Czech Republic and whether the liberalisation goals regarding prices have been fulfilled. Are they still coupled with light and heavy fuel oil and how, or are they decoupled and driven by the supply-demand relationship? Have they decreased?

We investigate the individual components of end-customer gas prices according to the value-chain and we define and structure the drivers of these components. We pay extra attention to oil-linked pricing in long-term contracts and the consequences of market liberalisation/unbundling.

We provide the reader with a case study from the Czech Republic, one of the Central and Eastern European countries, which, contrary to the old Member States, is buying most of its gas from one supplier (high import dependence, low supply diversity) and where the transmission and distribution network is characterised by a sufficient contractual and physical capacity. We stress that next to basic conditions on the European gas market (import dependency on external gas producers) individual legal and institutional conditions and the initial market structure of each Member State are also important for the results of the liberalisation process.

**Keywords:** gas prices, pricing, unbundling, liberalisation, long-term contracts, European Union, Czech Republic

**JEL Classification:** D4, L95, L1, L43, G34

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## 1. Introduction

The EU as a whole depends on imports from an oligopoly of important gas producers. It imports some 60% of its annual consumption, mainly from super-giant fields in Russia - 23% of the EU's annual consumption, Norway - 16%, Algeria - 10% and from further sources covering no more than 2% of annual consumption each. The import dependency of the EU-27 is expected to increase to 74% by 2030. Within the EU, only the Netherlands and Great Britain have their own gas sources worth mentioning (accompanying document to EC, 2010, pp. 40). On the other hand the Central and Eastern European countries of Estonia, Latvia, Lithuania, the Czech Republic, Slovakia, Poland, Hungary and Slovenia import the most or their total consumption only or mainly from Russia (World Energy Council, 2003).

Until recently, the prices of natural gas imported to continental Europe were based on long-term take-or-pay contracts.<sup>1</sup> They were determined by the price-development of gas substitutes such as heating oils, etc.<sup>2</sup> To exclude potential arbitrage by the buyers, import contracts often contained a destination clause: the use of gas was restrained to the destined market for which it was priced.

In the 1990s, a discussion between theoretical and practical economists took place with regards to increasing the effectiveness of European natural gas utilities. Suggestions for privatisation and liberalisation were made (Midttun, 1997 and 2001; Vickers and Yarrow, 1988; Newbery, 2001a and 2002c; Glachant and Finon, 2003) as well as suggestions to enforce the free access of third parties to gas networks (Glachant 1998; Glachant and Finon 2004).

In 1998 the European Union started reforms of the gas market in compliance with the USA/UK model. With the acceptance of Directive 98/30/EC, the European Union decided to open up the national gas markets to competition. The **liberalisation** of the gas sector and utilising the integrated pan-European network became a means of reaching **the single European market** in natural gas. The EU defined **unbundling**<sup>3</sup> as the primary means of originally vertically integrated market liberalisation.

Natural gas prices were expected to be **de-coupled** from oil prices; instead they should be **determined by the interaction of gas supply and demand** on newly established stock exchanges and secondary markets. They should be **pushed down** by the competition between shippers/traders/suppliers.<sup>4</sup>

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<sup>1</sup> High investments in the giant production fields and also in the long pipeline system between the gas reserves and distant consumer markets resulted in large import contracts often in an order of 5-10 Bcm/year with a duration of 20 years or more and with take-or-pay obligations both in gas supply and transit arrangements (Energy Charter Secretariat, 2007).

<sup>2</sup> The applied price formulas are often based on the replacement value: Gas is priced in relation to its substitutes (gas oil, heavy fuel oil or sometimes crude oil) so that there are just enough incentives over competitive fuels to use it.

<sup>3</sup> **1) The area of the “commercial activities” of gas import and supply was decided to be liberalised.** From liberalisation, the EU expects that new shippers/traders/suppliers (including international players) will enter the wholesale/retail market, and customers will be eligible to choose one where the products, services and prices suit them. **2) The area of naturally monopolistic network activities was designed to be regulated and harmonised.** The EU has formed independent national and supranational regulatory bodies, which set down the rules of fair access and transparent price setting with regards to transmission/distribution system operators (TSO, DSO). The EU anticipates that unbundled operators will secure fair access for competing shippers/traders/suppliers to the infrastructure.

<sup>4</sup> European Commission (2000b, p. 1): “Empowering the customer through customer choice will give rise to many effects, as it puts pressure on all operators along the gas chain to improve customer service, cut costs and reduce prices. Opportunities for new entrants into the gas market will increase this pressure to the advantage of customers.”

Until 2008 market liberalisation in Continental Europe has not been able to push prices down<sup>5</sup>. Although spot markets and financial markets for energy derivatives have been developed, they were not sufficiently liquid<sup>6</sup> and gas pricing remained mostly determined by long-term contracts. Yet in 2007 wholesale gas prices in most Member States remained similar, often competing offers on the retail market were unavailable or were too similar to amount to consumer switching.<sup>7</sup>

However, in 2009 the competition between European suppliers intensified, supported by the international financial and later economic crisis, which resulted in a significant fall in the consumption of natural gas. Excess supply over demand has created new opportunities for European power exchanges where more gas has been available at prices lower than the prices based on long term contracts. This put pressure on European importers and recently we can see a combination of oil-linked formula and market-pricing being introduced in long-term import and/or supply contracts (E.ON, ENI, Botas).

**The goal of this article** is to answer the question of how liberalisation influenced gas pricing/prices in the Czech Republic and whether the liberalisation goals regarding prices have been fulfilled. Are they still coupled with LTO, TTO and how, or are they decoupled and driven by a supply-demand relationship? Have they decreased? We pay attention to the main drivers of end-customer gas prices in the Czech Republic.

**With regards to the methodology, and contrary to other authors**, our contribution is in the perspectives we apply:

- 1) We use a case study from the **Czech Republic**, one of the Central and Eastern European countries, which, contrary to the old Member States, are buying most of their gas from one supplier (high import dependence, low supply diversity).
- 2) We provide the reader with a structural analysis in order to present the most important drivers of natural gas prices. Within the **Structure-conduct-performance scheme** we take the individual components of the end-customer-price according to the value chain as a performance indicator (i.e. the price of the imported commodity, of transmission, distribution and storage activities, the price of wholesale/retail supply activities) and we **define and structure the drivers of these individual price components**. We pay different attention to each price component with regards to its percentage presentation within the end-customer price. We put more emphasis on the consequences of market liberalisation/unbundling versus oil-linked pricing in long-term contracts.

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<sup>5</sup> For the percentage increase in prices see the benchmarking reports of the European Commission (2008, p. 6, incl. Accompanying document pp. 25-27), European Commission (2009, pp. 8-10).

<sup>6</sup> Although traded volumes in gas hubs increased from 40 bill. m<sup>3</sup> in 2003 to 120 bill. m<sup>3</sup> in 2007, the physical volumes delivered at most of the hubs are still relatively low compared to the total consumption in their markets (see the benchmarking report of European Commission (2009, pp. 4, 5).

<sup>7</sup> See the benchmarking reports of European Commission (2005a, p. 8) and (2008, p. 8).

## 2. *The literature review and theoretical background*

In this part of our article we summarise in which ways natural gas prices have been examined in theoretical and empirical sources. We divided the sources into three basic groups:

The first group of literature concentrates on **gas prices after European liberalisation** – we have found different and opposite meanings:

- The Energy Charter Secretariat (2007) explains the continuing differences in market structures, pricing mechanisms and liquidity between the regional gas markets of North America/United Kingdom vs. Continental Europe after the liberalisation. They conclude that these differences are not only a question of sector reform, but have something to do with supply structure and import dependency: 1) The North American, and to a lesser extent the UK, gas market has developed into a liquid spot and futures commodity market (hubs churn 100) with many players, where gas prices are no longer contractually pegged to heating oil prices.<sup>8</sup> This happened on the basis of domestic upstream competition (their own resources from multiple small- and medium-sized gas fields) and because the regulatory authorities had leverage on its natural gas supply over both upstream and downstream. 2) On the other hand, national gas markets in continental Europe developed on the basis of gas imported from a few super-giant fields in Russia, Norway and Algeria. The EU has no regulatory impact on the oligopoly upstream (the main EU suppliers are outside the EU's regulatory space). Consequently there are only few strong players, a few industry hubs with relatively low liquidity (churn < 10); long-term contracts with oil prices as reference in the price formula still dominate.
- Brakman, van Marrewijk and van Witteloostuijn (2009) cover the reasons for the potentially negative effects of liberalisation within the EU. They argue that the fact prices are determined in residual markets where the least efficient firms are active, is more likely to lead to price increases, rather than decreases.
- Iimi (2003), Bjoerkroth, et al (2006) point out two effects of unbundling and liberalisation. They stress that the benefits of introducing competition should be compared to the loss of synergies, which could emerge after the unbundling of vertically integrated energy utilities (VIU). Other authors warning of before-price increases due to the loss of synergies and/or other additional costs connected with unbundling are, e.g. Hattori and Tsutsui (2004), Steiner (2001), Michaels (2006), Kwoka and Pollitt (2007), Nemoto and Goto (1998), Newbery and Pollitt (1997), Domah and Pollitt (2001), PWC (2006), Mulder and Shestalova (2005).
- Willner (2003) and later Bjoerkroth, Groenblom and Willner (2006) came to the conclusion that liberalisation would have no need to bring more contribution than a welfare-maximising public monopoly, if the gas industry remained imperfectly competitive. Liberalisation could come about either by market consolidation or deepening horizontal integration, which ultimately could bring higher prices and a transfer of strategic decision making into the hands of a limited number of large companies. On the other hand Spanjer (2009) concludes that a transaction cost perspective provides better underpinnings for European gas regulation than the current neoclassical perspective and therefore questions the effects of the

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<sup>8</sup> But rather, follow their development due to substitution effects (above all dual-fired power plants make the demand elastic).



liberalisation as implemented at that moment. Policy-makers should recognise that less-than-perfect competition outcomes may be optimal.

- Stern (2007, 2009) argues that oil-linked pricing in continental European long-term gas contracts is not sustainable and presents his arguments for future replacement by an indexation to gas prices based on trading at market hubs.

The second group of authors provides the reader with a **cointegration analysis**:

- Opening national gas markets and their integration should lead to a convergence of prices. That is why some authors examine the cointegration of gas prices in different locations and periods of time: L'Hégaret and others (2003 and 2004) examine European/Japanese and North American markets; Cornot-Gandolphe (2003), Deutsche Bank (2003), and Jensen (2003) review Europe, North America and Asia; Serletis (1997) discusses the eastern and western part of North America; Asche, et al (2000) examines France, Germany, Belgium; Hirschhausen, et al (2006) tackles the UK and Belgium; Harmsen and Jepma (2011) examine six north-western European hubs.
- That prices of gas and the oil derivatives are strongly correlated is being supported by the price cointegration between different groups of petroleum products: Gjolberg and Johnsen (1999) and Asche, et al. (2001) discuss crude oil and major refined products; Serletis and Herbert (1999) discuss natural gas and fuel oil; Girma and Pauslon (1999) talk about crude oil, gasoline, heating oil; Brown and Yücel (2007) comment on natural gas and crude oil via residual fuel oil.

The third group of authors evaluates different **price forecasting models for different groups of petroleum products**:

- Longo, et al (2007) classifies different oil price forecasting models into “financial” models (based on the relationship between spot and futures prices), “structural” models (assigning a key role to variables explaining the characteristics of the physical oil market) and “standard time series” models (the random walk and the pure first-order autoregressive models do not rely on additional explanatory variables), evaluates them and concludes that models combining the three previous methodologies show the highest empirical performance.
- Pindyck (1998) examines the long-term behaviour of oil, coal and natural gas prices using 127 years of data. He estimates a model of mean reversion to a stochastically fluctuating trend line using the Kalman filter method. These non-structural models performed well in forecasting oil prices, but less well for coals and natural gas.
- Other authors evaluate different predictors of crude oil spot prices: Murat and Tokat (2008) detail crack spread futures and crude oil futures vs. the random walk model, Knetsch (2006) takes on “convenience yield” vs. futures prices.

### 3. Main drivers of end-customer prices in the Czech Republic: Price consequences of market reform vs. long-term contracts

Our goal in section 3 is to **define** and **structure** the main drivers of natural gas prices in the Czech Republic (mainly to demonstrate the price consequences of an oil-linked formula in long-term import contracts and of liberalisation/unbundling).

In chapter 3.1. we provide the reader with a short discourse on the initial conditions in the Czech Republic, on the implementation of EU legislative liberalisation and on the resulting end-customer natural gas prices. In chapter 3.2. and 3.3. we describe our methodology and data set. In chapter 3.4. we apply the Structure-Conduct-Performance scheme to the Czech Republic: we define and structure the main drivers of the individual components of end-customer prices according to the value chain: the commodity component (chapter 3.4.1.), the transmission and distribution component (chapter 3.4.2.), the storage component (chapter 3.4.3.) and the sales component (chapter 3.4.4.).

#### 3.1. Background

##### Initial Czech legal and institutional settings

Contrary to the old Member States, the Czech Republic is a small open economy with a sufficient contractual and physical capacity of the transmission network significantly connected to the European infrastructure from the East to the West. The Czech Republic imports 99% of its annual gas consumption. Until recently the import was solely based on long-term take-or-pay contracts (the diversification of sources is low: 75% of gas stems from the Russian producer Gazprom, 25% stems from Norwegian producers), later the traditional long-term gas was slightly replaced by market gas from European hubs.

##### Implementation of EU legislation

The Czech Republic successfully implemented three European gas directives on liberalisation/unbundling into its legal and regulatory system.

Table 1: Correlation table – the legal implementation of the first two gas directives in the Czech Republic

	98/30/EC	2003/55/EC	458/2000 Sb.	670/2004 Sb.
<b>Accounting unbundling</b>				
production, transmission, LNG, storage, distribution	10.8.2000	10.8.2000	1.1.2001	1.1.2001
supply to eligible and protected customers	--	1.7.2007	--	1.1.2005
<b>Legal and Functional unbundling</b>				
TSO	--	1.7.2004	--	1.1.2006
DSO	--	1.7.2004	--	1.1.2007
possible postponement of DSO unbundling?	--	YES, legal till 1.7.2007	--	YES, legal and funct. till 1.1.2007
possible exemption of L and F unbundling for smaller DSO?	--	YES, with < 100 th. customers	--	YES, with < 90 th. Customers
<b>Ownership unbundling</b>				
TSO, DSO	--	--	--	--
<b>Phased market opening</b>				
Gas-fired power generators, other final customers consuming more than 25 mcm of gas p.a.	20%*, 10.8.2000	30.6.2004	28%*, 1.1.2005	1.1.2005
Gas-fired power generators, other final customers consuming more than 15 mcm of gas p.a.	28%*, 10.8.2003			
Gas-fired power generators, other final customers consuming more than 5 mcm of gas p.a.	33%*, 10.8.2008		33%*, 10.8.2008	1.1.2006
All non-household customers	--	1.7.2004	--	--
Household customers	--	1.7.2007	--	1.1.2007
<b>Access to the system</b>				
Transmission network	regulated or negotiated	regulated	negotiated	regulated
Distribution network	regulated or negotiated	regulated	regulated	regulated
Storage	regulated or negotiated	regulated or negotiated	negotiated	negotiated

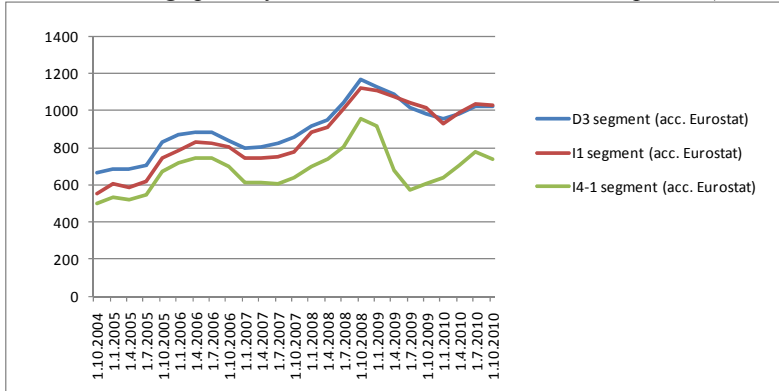
\*Minimum market share which had to be opened (from the total yearly consumption of the Member State)

Source: Authors, based on mentioned directives and laws

## Price development

Price development in the Czech Republic has been mixed from the point of view of different customer categories. Some of the biggest industrial customers experienced mentionable savings in the purchasing costs of gas. To the contrary, for the majority of other customers the anticipated decrease in the price of gas has not occurred. In 2009 the Czech Republic became the fourth most expensive EU Member State when measured by gas prices for household consumers in purchasing power parity<sup>9</sup>.

Chart 1: Average prices for end-customers in the Czech Republic (CZK/MWh, before VAT)



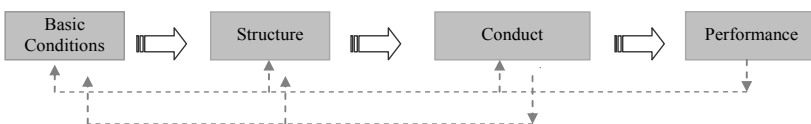
Source: Authors, based on National reports of the Energy Regulatory Office (2005, 2006, 2007, 2008, 2009, 2010, 2011).  
 Note: customer categories according to Eurostat, prices include all components (commodity, transmission, distribution, storage and sales).

## 3.2. Methodology

Our goal in chapter 3.2. is to **define** the main drivers of natural gas prices in the Czech Republic, mainly to demonstrate the price consequences of an oil-linked formula in long-term import contracts and of liberalisation/unbundling.

To **structure** the drivers of the end-customer prices in the Czech Republic, we use the so-called “**Structure-Conduct-Performance**” model (SCP), defined by Scherer (1980). He used the hypothesis that the Basic Conditions influence the market Structure. Basic Conditions and market Structure influence the Conduct of market players, thus further determining the sector Performance. The consequences also run in reverse (e.g. performance influences the market structure, etc).

Figure 1: Basic Scheme of the Structure-Conduct-Performance Model (SCP) according to Scherer (1980)



For the purpose of our analysis, we understand under Basic Conditions the basic features of the gas market:

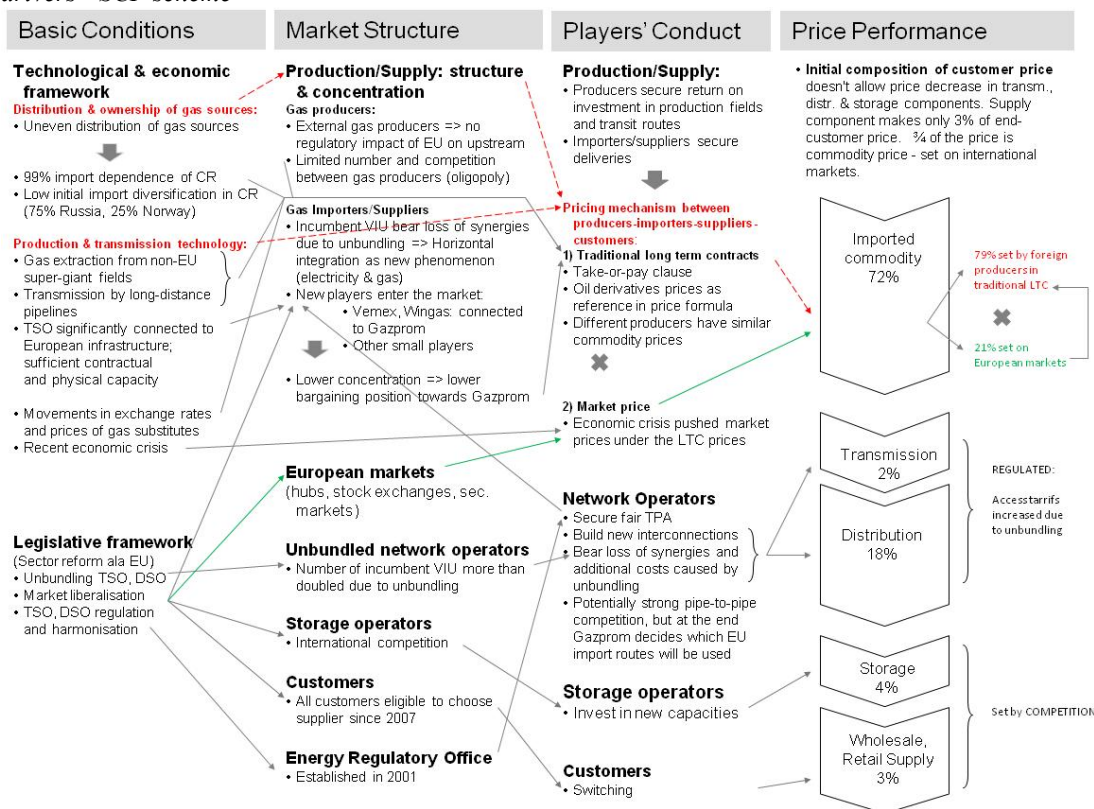
<sup>9</sup> Accompanying document to European Commission (2010), p. 21.

the technological and economic framework (import dependency, production and transmission technology, existence and prices of substitutes, supply and demand relationship, movements in exchange rates, etc.) and also the Czech-specific legal and institutional settings within which the sector operates (as described in chapter 3.1).

We further characterise the market Structure by the structure and concentration of market players. Under the player's Conduct we introduce the incentives and behaviour of market players and the resulting pricing mechanism which is used in the gas trade.

As a Performance indicator, we define end-customer prices. We observe individual components of end-customer prices according to the **value chain**. The price for the end-customer ( $P_{EC}$ ) consists of the price of the imported Commodity ( $P_{Com}$ ), the price of Transmission ( $P_{TSO}$ ), Distribution ( $P_{DSO}$ ), Storage ( $P_{SSO}$ ), and Wholesale/Retail Supply activities ( $P_S$ ).

Figure 2: End-customer prices in the Czech Republic: Percentage composition according to the value chain, Main drivers - SCP scheme



Source: Authors, based on the basic features of the gas market, the experience from the Czech Republic and the following documents: Directive 2003/55/EC, European Commission (2000 b, 2005 a,b, 2007 a,b,c,e), Joint Working Group of the European Gas Regulatory Forum (2001), Kroes (2007 a-c), Energy Charter Secretariat (2007).

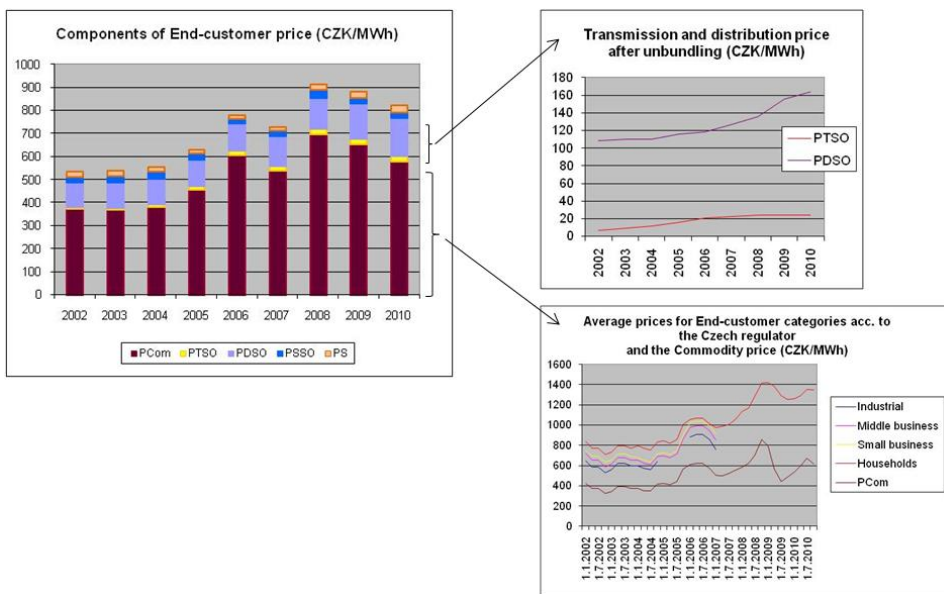
Note: As the percentage share of the individual components within the total end-customer price we used the average value from the 2002-2010 data, which we received upon request from the Czech regulator.

In Chapter 3.3. we describe our data set.

In chapter 3.4. we pay attention to each particular component of the end-customer price and we go through its drivers as we defined them in Figure 2.

Our attention differs according to the percentage presentation of the component within the end-customer price: in fact, the highest portion of  $P_{EC}$  makes the most volatile component - the commodity price  $P_{Com}$  - some 72%; about 18% of the end-price is determined by distribution; each of the remaining activities - transmission, storage and wholesale/retail supply - cover just 2-5% of the end-price.

Chart 2: Movements in the end-customer prices are mostly determined by movements in the commodity price, the second most important component is the distribution price



Source: Authors, based on data requested from the Czech regulator.

Note: With regard to market liberalisation, from all end-customer categories only prices for household consumers have been observed by the Czech regulator since 2Q/2007.

### 3.3. Data set

We observe the commodity prices at the border of the Czech Republic and also at the wholesale level, i.e. between the importer and the retail suppliers. At the retail level we observe end-customer prices including not only a commodity component but also a transmission, distribution, storage and sales component. On the wholesale and retail level only the prices of *incumbent* importer/suppliers are introduced, prices of entrants are observed neither by the Czech regulator nor by the statistical office.

The most complete time series are yearly or quarterly data from 1Q/2002-1Q/2007. Within this period, the systematic regulation of all price components took place in the Czech Republic, starting with establishing the Energy Regulatory Office and ending with price deregulation for the last group of customers according to

market liberalisation. The length of the time series is the most important factor limiting the depth of our analysis.

Table 2: Input variables for our analysis

	The commodity price at the border to the Czech Republic		The commodity price on the wholesale level - i.e. between the incumbent importer and the retail suppliers		End-prices for individual customer categories - including the commodity, transmission, distribution, storage and sales component						Individual components of the end-price for a hypothetical average Czech end-customer according to the value chain					
	The market price - TTF year ahead forward price	The estimation of the commodity price between the producers and the incumbent importer according to long-term contracts	Before corrections	After corrections	According to the segmentation of the Czech regulator				According to the segmentation of Eurostat							
Denotation	TTF	$P_{LTC}$	$P_m$	$P_{Com}$	Industrial	Middle business	Small business	Households	D3	I1	I4-1	$P_{Com}$	$P_{TSO}$	$P_{DSO}$	$P_{SSO}$	$P_s$
Period	daily data 1.1.2006-16.12.2010	monthly data 09/1993-12/2010	quarterly data 1q/2002-1q/2007	quarterly data 1q/2002-4q/2010	quarterly data 1q/2002-1q/2007			quarterly data 1q/2002-4q/2010	quarterly data 4q/2004-4q/2010			yearly data 2002-2010				
Units	EUR/MWh	CZK/MWh	CZK/MWh		CZK/MWh				CZK/MWh			CZK/MWh				
Source	Thomson Reuters	Authors, based on Brent (respectively LFO, HFO) and ER data*	Czech regulator upon request		Czech regulator upon request				National reports of the Czech regulator			Czech regulator upon request				

Source: Authors

In order to estimate the monthly  $P_{LTC}$  time series in the abovementioned table we use the following data (for more details see the technical annex):

Table 3: Supportive input variables for our analysis

	Gasoil Amsterdam-Rotterdam-Antwerp (ARA) Gasoil - Spot price FOB	Residual Fuel Oil Amsterdam-Rotterdam-Antwerp (ARA) Residual Fuel Oil Sulphur < 1.0 - Spot price FOB	Crude oil Europe Brent - Spot price FOB	Exch. rate
Denotation	LFO	HFO	Brent	ER
Period	Monthly data 09/1993-06/2008		Monthly data 09/1993-12/2010	
Units	Cents per Gallon*		USD/Barrel	CZK/USD
Source	<a href="http://eia.doe.gov">http://eia.doe.gov</a> , section Prices-Spot Prices-Dow nload series history			<a href="http://www.cnb.cz">www.cnb.cz</a>

Source: Authors

\*Note: on the European market (NEW, Rotterdam, ICE) the prices of LFO and HFO are quoted in USD/ton. We have sourced our time series from EIA, which quotes these prices in Cents per Gallon in order to enable the comparison of prices on North American and European markets.

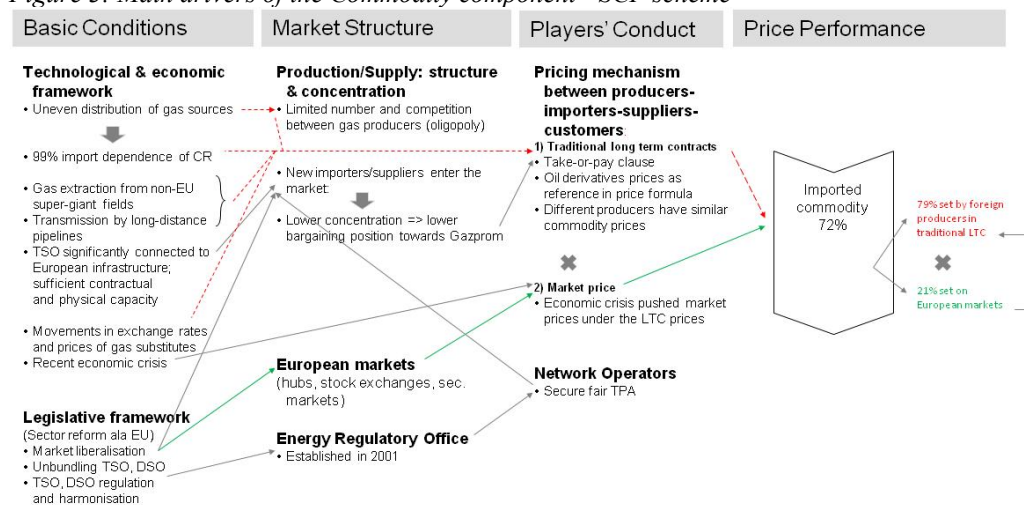
### 3.4. Application of the SCP Model

In chapter 3.4. we pay attention to each component of the end-customer price (according to its percentage presentation) and we go through its drivers as we defined them in Figure 2.

#### 3.4.1. The commodity price

The price of the imported commodity is the most powerful factor influencing gas prices for Czech end-customers (72% within the end-customer price).

Figure 3: Main drivers of the Commodity component - SCP scheme



Source: Authors

Before market opening, all imports to the Czech Republic were based on long-term contracts (LTC) with Russian and Norwegian producers (see more in the technical annex). European liberalisation enabled additional gas – the market-priced gas from European hubs – to be imported into the Czech Republic. Recently the excess supply over demand (due to the financial and later economic crisis and also due to some new sources of gas found) caused market prices to fall below the LTC-price. Thus, within the total imports to the Czech Republic, the share of long-term gas has gradually declined from 100% in 2005 to some 79% in 2010 in favour of the market-priced gas.

Table 4: Imports to the Czech Republic (according to volumes)

	Long term contracts Russia+Norway	Market Germany/EU
2005	100.00%	0.00%
2006	99.65%	0.35%
2007	99.98%	0.02%
2008	97.49%	2.51%
2009	93.41%	6.59%
2010*	79.18%	20.82%

Source: Authors, based on data requested from the regulator (as of April 2011)

\*Note: since 2010 the regulator has not been able to differentiate exactly between LTC vs. market. Introduced is the differentiation between Russia/Norway vs. Germany/EU imports.

In this chapter we want to show that market liberalisation in the Czech Republic has had several effects not only on **commodity sourcing** but also on its **pricing**.

We distinguish four types of commodity prices:

- 1) The *commodity price at the border* of the Czech Republic:
  - a. paid by the importers to producers according to long-term-contracts – let us denote it  $P_{LTC}$ ,
  - b. settled on European hubs – TTF,
- 2) The resulting *commodity component within the end-price*:
  - a. of a hypothetical average Czech end-customer -  $P_{Com}$
  - b. of each individual customer category according to Eurostat D3, I1, I4-1.

### **Our hypothesis:**

We make the following hypothesis for the Czech Republic with regard to the goals of European liberalisation:

**H1:** After the European liberalisation the *pricing mechanism of  $P_{Com}$  changed*. We want to show that  $P_{Com}$  firstly reflected the costs of gas imported according to long-term-contracts, but with the emergence of the European hubs the correlation with  $P_{LTC}$  decreased and the correlation with market prices emerged.

**H2:** After the European liberalisation the *pricing mechanism (oil-linked or market-based) of the commodity component differs via different customer categories*. We want to show that especially by more elastic industrial and middle-sized business customers the long-term contracts stopped being relevant; instead market prices are relevant. We expect these customer segments to experience savings through (the opportunity of) switching to new suppliers offering cheaper market-priced gas.

**H3:** In the long-run the European liberalisation should also lead to a change in the pricing mechanism of the *commodity price  $P_{LTC}$* . A mixed formula containing both oil-linked and gas-indexed prices could be the expected result.

### **The analysis:**

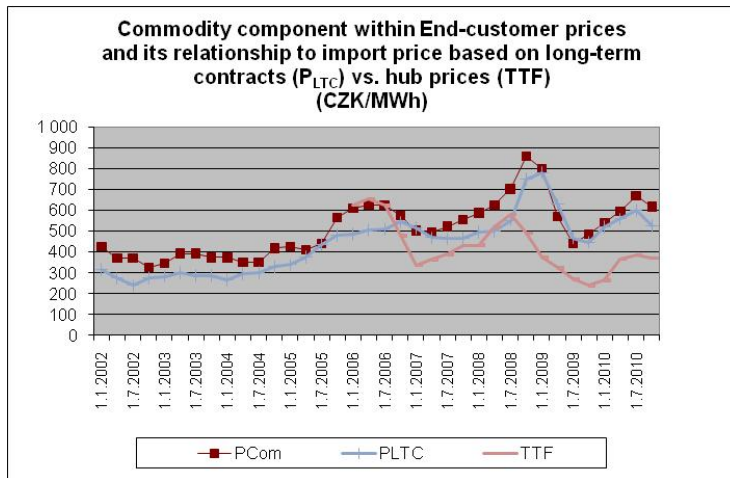
With regard to H1 and H2 we have examined the dependency of end-customer prices on two different border commodity prices: our approximated  $P_{LTC}$  time series should be the main price driver up to the point of market liberalisation, whereas the commodity price in TTF gas forward contracts should influence end customer prices since the liberalisation has been put into force. Our goal is to find out which of these two different market factors influence end-customer prices more.

#### **ad H1:**

In the first stage, we analysed the significance of the pricing switch possibly hidden in  $P_{Com}$ . Our hypothesis was that until 2005,  $P_{Com}$  price was dependent on our approximated  $P_{LTC}$  and from 2006 on TTF gas forwards.



Chart 3: The commodity component  $P_{Com}$  entering end-customer prices, the estimated  $P_{LTC}$  in long-term import contracts for the Czech Republic, year ahead forward prices of gas traded at TTF hub



Source: Authors, based on the commodity component within the end-customer prices provided by the regulator, on Brent-data in order to estimate  $P_{LTC}$  (see the technical annex), on TTF forward prices listed at Thomson Reuters and on exchange rates quoted by the Czech National Bank.

We estimated two regression equations:

$$P_{Com} = \alpha + \beta \cdot P_{LTC} + \varepsilon \quad (i)$$

$$P_{Com} = \alpha + \beta \cdot TTF + \varepsilon \quad (ii)$$

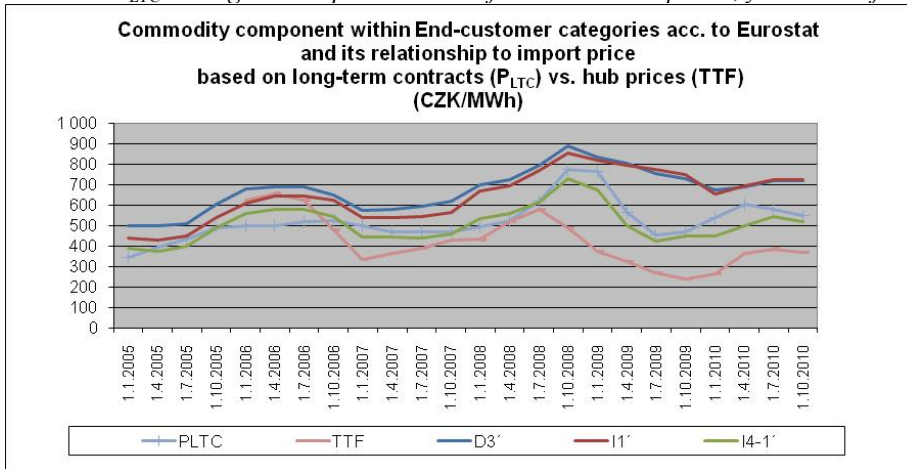
In both equations, we performed a Chow's test of structural break in coefficients values. Our hypothesis that the  $P_{Com}$  was driven by different time series was not true – the second equation did not prove any structural break in the regression coefficient. This might be caused by the fact that the dataset of TTF forwards starts in 2006, which is too short period to find significant changes in regression coefficients. On the other hand, in the first equation, the Chow's test proved at a 90% confidence level that there is a structural break in the regression coefficient of  $P_{Com}$  determinant  $P_{LTC}$  in 4Q/2005 – this can be explained by market liberalisation.

Our second finding was a decreasing spread between  $P_{Com}$  and  $P_{LTC}$  during 2009 after  $P_{Com}$  was attracted closer to the TTF forward price, however still copying the shape of  $P_{LTC}$ .

## ad H2:

In the second stage, we examined the behaviour of the commodity component within individual end-customer categories according to Eurostat. The first category, D3, consists of individual households. The other segments, I1 and I4-1 are commercial customer categories, where the former is an SME and the latter a corporate segment.

Chart 4: The commodity component within individual end-customer categories D3, I1, I4-1 according to Eurostat, the estimated  $P_{LTC}$  in long-term import contracts for the Czech Republic, year ahead forward prices of gas traded at TTF hub



Source: Authors, based on the prices of different end-customer categories according to Eurostat, on Brent-data in order to estimate  $P_{LTC}$  (see the technical annex), on TTF forward prices listed at Thomson Reuters and on exchange rates quoted by the Czech National Bank.

We estimated three separate models and analysed the response of individual categories to both  $P_{LTC}$  and TTF forwards.

$$P^i = \alpha + \beta \cdot P_{LTC} + \varepsilon \quad (iii)$$

$$P^i = \alpha + \beta \cdot TTF + \varepsilon \quad (iv)$$

Where  $P^i$  denotes the commodity price for the  $i$ -th segment (i.e. D3-households, I1-SMEs and I4-1-corporates).

Because we face an autocorrelation issue, we have transformed all time series into log-changes.

According to the regression results, the household segment price can be better explained by forwards. The adjusted coefficient of the determination is 44%, which is very high for a regression with only one explanatory variable. Both the homoscedasticity and the normality of residuals could not be rejected.

The industrial segment I4-1 (corporates) showed autocorrelation even with log-changes so we employed an autoregressive estimation with lag1. The model was estimated by the Cochrane-Orcutt method. Our results show that the I4-1 segment price depends more on the  $P_{LTC}$  than on the TTF forward price. This is a contradictory result as we expected that the end-price for corporate customers would be the first to gain from market liberalisation. However, a strong adjusted coefficient of determination (56%) demonstrates the opposite.

Our analyses showed that although market liberalisation took place several years ago, end prices set by incumbents for corporate customers are still resilient and heavily depend on long-term contracts. On the other hand, prices for households behave more marketwise. For I1-customer prices we cannot present definitive

results. This contradictory conclusion could probably be explained by the transcription of the pricing formula from long-term import contracts into the contracts between incumbent suppliers and corporate customers or maybe also some I1 customers. In Chart 4 we can see that prices for corporates move together with  $P_{LTC}$ , but fall faster than TTF, whereas D3 and I1 prices fall more slowly than TTF. This suggests that incumbent suppliers did not remove the formula from contracts with corporates, but at the same time they provided corporates with a discount to a disadvantage of D3 and I1 sector.

However, the liberalised market is still very young and thus more time is needed to support our results with additional analysis. Already today, we can see an increasing trend in supplier switching: in the first quarter of 2011 the number of consumers that switched their gas supplier exceeded the number of switching customers in the whole of 2010. The incumbent importer has lost some 36% of the market so far and expects other losses in the market share up to 50% in 2011. Thus, new products are being prepared by incumbents for their customers in 2011.

Table 5: Consumer switching in the Czech Republic

Number of customers at the market							
	2005	2006	2007	2008	2009	2010	2011 (1-3)
Industrial	2 043	2 054	1 979	1 911	1 743	1 742	1 708
Middle business		7 556	7 724	6 838	6 714	7 022	7 009
Small business		187 556	192 206	198 771	199 000	192 984	198 285
Households			2 643 520	2 657 056	2 664 090	2 644 938	2 659 592
Total	2 805 705	2 823 102	2 845 429	2 864 576	2 871 547	2 846 686	2 866 594
Number of switching customers							
Industrial	2	2	104	129	152	213	425
Middle business	NA	24	9	90	267	674	726
Small business	NA	428	62	366	4 506	6 842	9 812
Households	NA	NA	6 524	11	28 402	76 695	63 726
Total	2	454	6 699	596	33 327	84 424	74 689
Percentage share of switching customers							
Industrial	0%	0%	5%	7%	9%	12%	25%
Middle business	NA	0%	0%	1%	4%	10%	10%
Small business	NA	0%	0%	0%	2%	4%	5%
Households	NA	NA	0%	0%	1%	3%	2%
Total			0%	0%	1%	3%	3%

Source: authors, based on <http://www.eru.cz>

Note: The market was opened in 2005 for industrial customers, in 2006 for middle-sized and small business customers, in 2007 for households.

### ad H3:

Recently, the excess supply of gas and low market prices generated pressure on the incumbent importers that were buying their long-term gas upon take-or-pay contracts. The reduction of the *minimum-take-volume* and a *mixed formula* containing both oil-linked and gas-indexed prices would help their situation. However, market liberalisation in the Czech Republic leads to a lower market concentration (entries of new suppliers are also supported by a sufficient transmission and distribution capacity, securing a fair TPA by TSO and DSOs), which *weakens the position of incumbent suppliers bargaining the LTC towards Gazprom*.

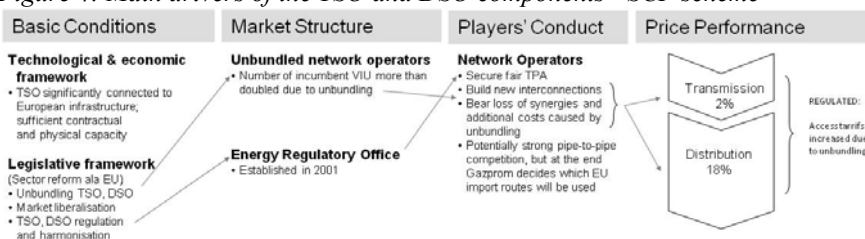
### 3.4.2. The price for transmission and distribution

The transmission and distribution components ( $P_{TSO}$ ,  $P_{DSO}$ ) of end-customer prices are regulated and remain at the same level during the whole year. They are calculated on the cost-plus basis to cover operating and capital costs for both debt and equity services.

In the Czech Republic end-customer natural gas prices have increased as a result of unbundling. Most of the unbundling costs have been acknowledged by the regulator and was/will ultimately be borne by the customers in several previous and following years.

On the other hand, we can see more and more pressure from the EU on reducing the regulated margins of European TSOs – the “plus” component of the  $P_{TSO}$ .

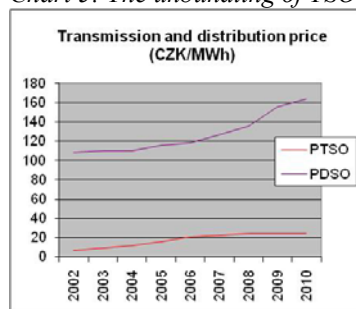
Figure 4: Main drivers of the TSO and DSO components - SCP scheme



Source: Authors

Year-to-year growth was mainly explained by additional costs resulting from the implementation of the accounting, functional and legal unbundling of TSO and DSO operators:

Chart 5: The unbundling of TSO and DSOs caused growth in end-customer prices



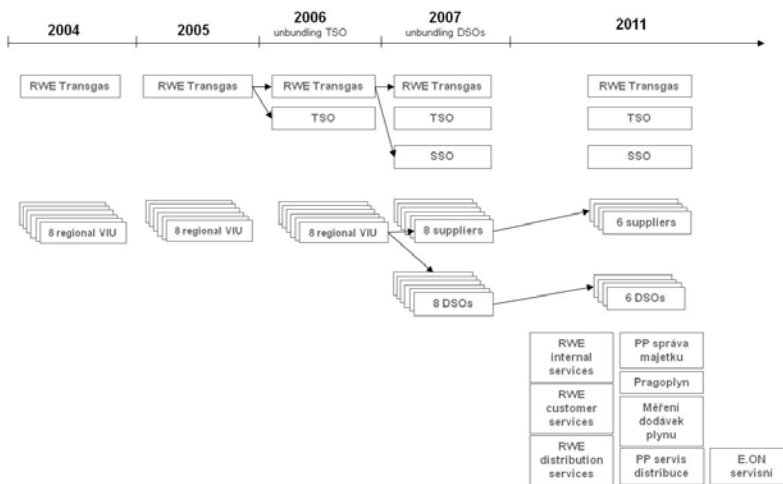
Source: Authors, based on data requested from the regulator

- 1) Accounting unbundling led to the correct allocation of costs and removed cross-subsidisations<sup>10</sup> between the activities of international transit and national transmission (since 2001), and later between customer categories of industrial and domestic (since 2004). Accounting unbundling showed that before its implementation, end-customer prices did not reflect the real costs of gas companies.
- 2) In the Czech Republic there are 3 main investor groups (RWE, E.ON and PP) in the gas business after the privatisation. The TSO has been legally unbundled since 2006, and 8 DSOs since 2007. Legal unbundling

<sup>10</sup> Typical during the CMEA times (The Council of Mutual Economic Assistance).

has led to an increase in the number of companies from 9 VIU in 2004 to 23 in 2011! Thus, legal unbundling led to *the loss of synergies of the original vertically integrated undertakings*, above all in the sphere of internal services such as human resource management, finance and accounting, controlling, procurement etc.

Figure 5: Increase in the number of incumbent VIU after the unbundling of TSO, DSOs in the Czech Republic



Source: Dočekal (2007), for 2011 adjusted by the authors according to [www.rwe.cz](http://www.rwe.cz), [www.ppas.cz](http://www.ppas.cz), [www.eon.cz](http://www.eon.cz)

Note: RWE internal services provides the RWE group with central purchasing, IT, human resources and car fleet management; RWE customer services provides RWE customers with offices, a call centre, invoicing and enforcement of receivables; RWE distribution services provides 4 DSOs within RWE group with operation and maintenance of the distribution facilities; PP správa majetku provides the PP group with the operation of buildings, car fleet management etc.; Pragoplyn takes care of gas purchases, gas storage management and customer acquisitions for PP-supplier; Měření dodávek plynu provides PP-DSO with gas metre readings, metrology etc.; PP servis distribuce provides the PP-DSO with operation and maintenance of the distribution facilities; E.ON servisní provides the E.ON-DSO with operation and maintenance of distribution assets;

- 3) The implementation of unbundling led to *one-time operational and investment costs* - legal, organisational, tax, accounting and economic advisory costs; splitting the information and accounting systems, respectively buying new ones; splitting the companies and their rebranding; evaluation of shared services and conclusion of service-level-agreements - and in the future will lead to other *recurring operational and investment costs* such as hardware and software maintenance, renewing IT licences, and more personal costs in connection with loss of synergies.
- 4) Other extra costs have been caused by the revaluation of transferred transmission and distribution assets and the corresponding *revaluation of their depreciation*.

### 3.4.3. The price for storage activities

Gas storage has a negotiated TPA according to Czech law. The percentage presentation of the price of storage  $P_{SSO}$  within  $P_{EC}$  is small, in the years 2002-2010 it moved between 3-5%. The price of storage stopped being determined on a cost-plus principle, instead the spread between winter and summer natural gas prices is the most important determinant.

Figure 6: Main drivers of the Storage component - SCP scheme



Source: Authors

Initially after the market opening, the price for storage was held artificially low. This led to an excess demand over the supply (capacity was demanded even by international players). Deregulating the price led to its gradual adjustment to an international price level according to international competition and due to expected investments into capacity extensions.

However, in the last auctions of 2010 some storage capacity has not been placed. There are two reasons: 1) the supply of gas storage not only in the Czech Republic but also in the rest of Europe increased, 2) after the spreads between winter and summer market prices of natural gas were pushed down by the economic crisis, suppliers partly replaced storage services by market – they structure their deliveries via combining purchases and sales on the market.

### 3.4.4. The price for wholesale/retail supply activities

In the Czech Republic the  $P_S$  component was already negligible before market liberalisation – influenced by the decision of the regulatory office (3% of the total price for end-customers). Originally we thought that the initial low base of this component did not allow its decrease, that the potential of savings created by the competition of suppliers through reducing their margins was very limited, contrary to, e.g. Great Britain where high wholesale and/or retail margins had been achieved before liberalisation.

But currently low market-prices forced the incumbent importer to sell the gas on the wholesale market under the purchasing costs resulting from long-term contracts, thus with a *negative margin*. At least some corporate customers achieved noticeable savings in 2010.

#### Our hypothesis:

For the purpose of our paper and with regard to the goals of the European Commission we make the following hypothesis:

**H4:** After the European liberalisation the margins of incumbent suppliers in the Czech Republic decreased.

### **The Analysis:**

We analysed the behaviour of differences between the end-customer prices and TTF forward contracts or, alternatively,  $P_{LTC}$ . Our assumption was that the differences form an autoregressive process (AR), which is very strong for households and weaker for corporates. This would suggest that margins at the household sector are, despite the liberalisation, persistent, whereas margins at the corporate sector were allowed to decrease (which is visible from Chart 4).

To summarise our assumptions, we provide a mathematical notation:

$$R1_{households,t} = \alpha + \beta \cdot R1_{households,t-1}, \text{ where } R1_{households} = \ln(P_{LTC} - P_{houseolds}) / P_{LTC} \quad (v)$$

$$R2_{households,t} = \alpha + \beta \cdot R2_{households,t-1}, \text{ where } R2_{households} = \ln(TTF - P_{houseolds}) / TTF \quad (vi)$$

$$R1_{corporates,t} = \alpha + \beta \cdot R1_{corporates,t-1}, \text{ where } R1_{corporates} = \ln(P_{LTC} - P_{corporates}) / P_{LTC} \quad (vii)$$

$$R2_{corporates,t} = \alpha + \beta \cdot R2_{corporates,t-1}, \text{ where } R2_{corporates} = \ln(TTF - P_{corporates}) / TTF \quad (viii)$$

We have estimated all four AR1 processes. Our results are summarised in the following table. Regarding the dependency of margins calculated from TTF, it is visible that they react quite similarly. However, the problem is that these results have very weak explanatory power. Thus we should focus more on the results calculated from  $P_{LTC}$ . These clearly show that the beta coefficient is bigger at the corporate sector, suggesting that the margins at this sector are more persistent. This result supports our results from the H2 analysis.

*Table 6: Regression results*

Dependent variable	Beta coefficient (p-value)
$R1_{households}$	0.41 (0.0264)
$R2_{households}$	0.88 (<0.0001)
$R1_{corporates}$	0.61 (0.0002)
$R2_{corporates}$	0.88 (<0.0001)

*Source: Authors*

## **4. Conclusion**

In our article we deal with end-customer prices of natural gas after the European market liberalisation. In the introduction we remind the reader of the EU vision regarding gas market liberalisation and we confront this with the real outcomes as presented in the benchmarking reports of the European Commission. In the main section we concentrate on end-customer prices in the Czech Republic - we proceed with a structural analysis to define and structure the drivers of the individual components of end-customer natural gas prices according to the value chain. We stress that next to basic conditions on the European gas market - the lack of self-sufficiency and the geopolitical dependency on the importation of much of Europe on the oligopolic nature of only a limited number of important gas producers outside the EU's regulatory space - individual legal and institutional conditions and initial market structure of each Member State are also important for the results of the liberalisation process.

### **The starting position of the Czech Republic**

The Czech Republic is a small open economy with a sufficient contractual and physical capacity of TSO and DSO networks, depending on gas imports for 99%, with a low initial diversification of sources (25% Norway, 75% Russia). The Czech Republic is a transition economy having a specific percentage composition of end-customer prices: the highest portion of end-customer price makes the most volatile component - the commodity price (some 72%), about 25% of the end-price is determined by transmission, distribution and storage activities, and just 3% of the price is obtained by wholesale and retail supply activities.

**Our goal** was to answer the question of how liberalisation influenced gas pricing/prices in the Czech Republic, whether the liberalisation goals regarding prices have been fulfilled and what are the main drivers of natural gas prices here.

### **How market liberalisation influenced the individual components of end-customer prices?**

In the Czech Republic the implementation of European proposals (liberalisation/unbundling) touches all components of the end-customer price:

#### The commodity component:

So far, the commodity component in the end-customer prices reflected the oil-linked formula from the long-term import contracts. We have shown how the commodity price for the Czech Republic can be estimated from the development of the LFO and HFO price (see the technical annex).

*The market liberalisation influenced the commodity sourcing and with it also its pricing.* To the existing oil-linked long-term gas, more volatile market-priced-gas from European hubs came into the Czech Republic. The recent economic crisis and the excess supply over demand of gas caused, that market prices are under the price



of gas imported via the long-term contracts. This situation has an *impact on both the commodity component within the end-customer prices and also the purchasing price of the commodity imported via the traditional long-term-contracts*: a) we observed a structural break in the behaviour of  $P_{Com}$  determinant  $P_{LTC}$  at the end of 2005. This can be explained by market liberalisation. We can see a decreasing spread between  $P_{Com}$  and  $P_{LTC}$  during 2009 after  $P_{Com}$  was attracted closer to TTF forward price, however still copying the shape of  $P_{LTC}$ . The commodity component by domestic consumers stopped being determined by long-term contracts and is related to more volatile and recently cheaper market prices. On the other hand, the commodity component by corporate customers still moves with  $P_{LTC}$  but we could observe discounts which have been provided in order to get closer to the market price. b) the recent situation generates pressure on the reduction of the minimum-take-volume and on including gas-indexed prices into the formula within the long-term-contracts. However, the liberalisation in the Czech Republic weakens the market share of the incumbent importer and with it also its bargaining position towards Gazprom.

The transmission and distribution components have increased because of a loss of synergies and other additional costs resulting from the unbundling. Substantial influence has had the increased depreciation related to the revaluation of transferred transmission and distribution assets. These are unintended *negative side effects* created by the EU reforms. Regarding the “plus” component, the regulator exerts pressure on the regulated margins of the TSO and the 8 DSOs and we can expect further pressure on the price of the transmission resulting from potentially strong pipe-to-pipe competition.

The storage component increased to the international level and started to be determined by supply-demand relationship rather than by cost-plus principle.

Regarding the supply component, originally we thought that the initial low base of this component within the end-customer price does not allow its decrease. But currently low market prices forced the incumbent importer to sell its gas on the wholesale market under the purchasing costs resulting from the take-or-pay clause within the long-term contracts, thus with *a negative margin*. This situation would not be sustainable for a long-term. We have found decreasing margins between the price of different customer categories and  $P_{LTC}$ , however, contrary to our hypothesis, the margins by corporates are more persistent than those for domestic customers. This could be explained by the persistent transcription of the formula from take-or-pay contracts to corporate customer contracts and at the same time by providing discounts to corporates in order to get closer to market prices. However the liberalisation is still young and incumbent suppliers start to offer new products to their customers in 2011.

### **Have the liberalisation goals regarding prices been fulfilled (are the prices lower, decoupled?)**

The price development in the Czech Republic has been mixed from the point of view of different customer categories.

At least some *industrial and middle-sized-business customers* experienced savings in purchasing costs of gas, resulting from (the opportunity of) switching to suppliers offering cheaper market-priced gas.

On the other hand, by most of *domestic customers* the anticipated decrease in the price of gas has not occurred yet. The effect of the price increase in the transmission/distribution components as a consequence of unbundling and in the storage component due to its low initial base has not been outweighed by the effect of savings from introducing competition into the area of supply. In 2009 the Czech Republic became the 4<sup>th</sup> most expensive EU-member state when measured by gas prices for household consumers in purchasing power parity.

With regard to decoupling, on the *import level*, only 7% of the commodity has been decoupled from oil prices until 2009 (and is settled on European spot exchanges according to the supply-demand relationship). However, on the *retail level* (the commodity component within the end-customer prices), in the time of extremely low market prices, even such little imported volume worked as an accelerator for decoupling.

One could raise the question of whether oil-linked pricing of natural gas in the long-term import/supply contracts is sustainable. In fact: 1) There still remain high volumes of long-term gas imported from far away non-EU countries, 2) Producers are not interested in 'market-priced' long-term contracts; they would like to keep the traditional oil-linked formulas as long-term contracts are used to finance upstream projects, 3) The bargaining position of importers towards Gazprom weakens with decreasing market concentration, 4) The excess supply of gas over demand, which is now pushing market prices of gas down, will not last forever. So, for the future, we foresee that a different combination of oil-linked/market prices with price options/reviews on the side of importers and/or suppliers will be the norm in the Czech Republic. The longer the excess supply over demand, the higher the pressure on decoupling of gas prices from oil.

### **What are the most important drivers of natural gas prices in the Czech Republic?**

With regard to the initial composition of the end-customer prices in the Czech Republic, the most important component is the price of the imported commodity. So, the most powerful factors being able to bring gas prices down remain the decreasing *price of oil derivatives*, strengthening the *exchange rate of the CZK* and the *willingness* of (incumbent or newly entering) gas producers/suppliers. With the market liberalisation, *the global supply-demand relationship* takes on importance: whereas on the supply side different extraction peaks and/or new gas sources found/imported play a role, the demand side is determined by economic growth/recessions, consumption savings or by substitution effects of competitive fuels in different regions of the world. In this respect, different circumstances such as debates on exploration of European shale gas, redirections of LNG to Japan after the accident of Fukushima nuclear reactor or shutting down German nuclear power stations play important role.

### **What else can we conclude for the Czech Republic according to the Structure-Conduct-Performance scheme?**

In the Czech Republic the commodity imports remain mostly based on *long-term contracts*. The cause is the key characteristics of the gas market, the basic conditions, which can not be changed by any reform, namely the uneven (oligopolistic) distribution/ownership of gas sources and the corresponding cost-intensive production (super-giant extraction fields) and transmission technology (long-distance transit pipelines).

Unfortunately, the market reforms *strengthen an imbalance* between a limited number of strong producers (i.e. Gazprom), on one hand, and the suppliers, which are exposed to competitive pressure, on the other. The impossibility of changing these key characteristics of the gas market indicates that an important challenge will be the active foreign policy of the EU, aimed either at opening markets beyond the EU border or at protecting fragile European competition.

For the future, the European Commission expects developing pressure on decreasing the TSO component via enforcing the pipe-to-pipe competition in Europe. One important note needs to be mentioned here: letting Gazprom to participate as co-investor in building new pipelines to Europe (The South Stream pipeline, the North Stream pipeline, etc) again strengthens its position, it gives Gazprom additional decision power on, which import routes will be used. Therefore, it is a question of how fair the pipe-to-pipe competition will be.

Strengthening pressure on decoupling the commodity price of gas from oil prices could potentially end-up with creation of *a gas cartel* as an answer of important gas producers to the EU liberalisation.

## 5. Technical annex

In the technical annex we analyse the dependency of the price of commodity  $P_m$  imported via long-term-contracts on the price of light fuel oil (LFO) and heavy fuel oil (HFO).

The commodity price in import contracts  $P_m$  is given by a formula and so far depends on the average prices of competing commodities - heavy fuel oil (HFO), light fuel oil (LFO) and coal - from several previous months. Since imported gas is paid in USD or EUR, prices for Czech end-customers depend also on the exchange rate of CZK/USD and CZK/EUR. Contrary to the smoothing effect of moving averages applied on oil derivatives in the formula, movements in the exchange rate make the CZK commodity price more volatile.

$$P_m = \{P_0 + \alpha * (LFO - LFO_0) + \beta * (HFO - HFO_0) + \gamma * (COAL - COAL_0)\} * ER^{11} \quad (i)$$

### Our methodology and data

We try to estimate Equation (i). For this purpose we employ a linear regression analysis. We use a dataset consisting of average monthly prices from the period September 1993 to June 2008 (see Table 3 in the main text).

Since the quarterly data of the commodity price  $P_m$  provided by the regulator (21 cases) would be too limited for any deeper analysis, we try to estimate the monthly time series, which is not publicly available. Until 2009 the price used by the Czech TSO for balancing gas — let us denote this  $P_{LTC}$ — was not far from the actual  $P_m$ .  $P_{LTC}$  can be used to replace the true observed  $P_m$ . We have estimated the relationship between  $P_m$  and  $P_{LTC}$  and a linear regression analysis shows that the relationship is linear and very significant with R-square nearly 80% and a coefficient beta of 0.9.

With regard to the theoretical background, we focused on the thesis that  $P_m$ , depending on the LFO and HFO price, has a relationship to oil prices. We first estimate  $P_{LTC}$  based on the relationship to the price of crude oil, announced by the regulator (see Equation ii), and then substitute it for  $P_m$ .

$$P_{LTCi} = (2,5 + 0,36 * Brent_{MA9(i-1)}) * ER_{i-1} \quad (ii)$$

$$P_m \approx PLTC \quad (iii)$$

Where:

$P_{LTCi}$  is the monthly price for balancing gas in month  $i$  expressed in CZK/MWh

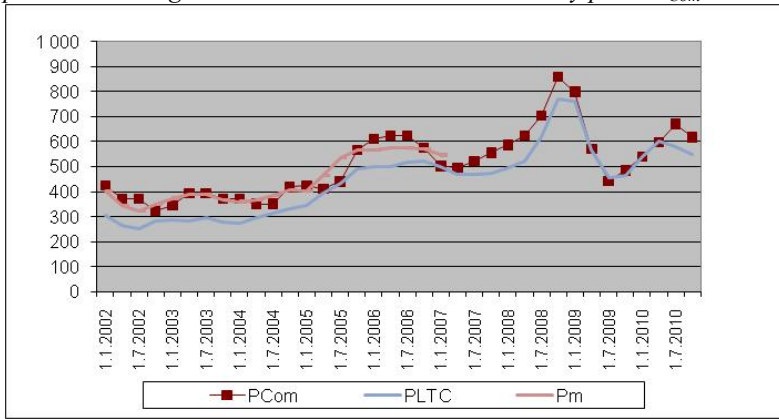
$Brent_{MA9(i-1)}$  is the ICE Brent index calculated as the moving average from nine previous calendar months expressed in USD/bbl, where  $(i-1)$  is the last month used for the calculation of the moving average

$ER_{i-1}$  is the average exchange rate of CZK/USD calculated from the daily data of the month  $(i-1)$  expressed in (CZK/USD)

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<sup>11</sup> We use the formula from Kajtman, M. (2006).

Chart 1: Estimating the commodity price  $P_{LTC}$  based on the oil price and its comparison to the true observed commodity price  $P_m$  in long-term contracts and to the commodity price  $P_{Com}$  within end-customer prices. (in CZK/MWh)



Source: Authors, based on oil prices and data from the regulator.

After receiving an estimated monthly time series of  $P_{LTC}$ , we may start with estimating Equation (i). Since we do not have a monthly time series for the price of coal, our relationship could be biased, however we do not assume high impact of our omission of the coal price in the estimated regression because of the likely correlation between coal prices and the heavy oil price. We know that in the Czech Republic the reference period, from which the moving average is computed, differs for different substitutes and falls between 6-9 months<sup>12</sup>. Based on the correlation analysis, we set the time lag of the reference period to 1, which means we set  $(i-1)$  as the last month for the calculation of the 6-to-9-months moving average.

Now we can define our model as follows:

$$P_{LTCi} = (P_0 + \alpha * HFO_{MAx(i-1)} + \beta * LFO_{MAy(i-1)} + u_i) * ER_{i-1} \quad (iv)$$

Where

$HFO_{MAx(i-1)}$  is the HFO moving average of  $x$  previous calendar months expressed in Cents/gallon,  $x$  being alternatively 6, 7, 8 and 9,  $i-1$  being the last month for the calculation of the moving average,

$LFO_{MAy(i-1)}$  is the LFO moving average of  $y$  previous calendar months expressed in Cents/gallon,  $y$  being alternatively 6, 7, 8 and 9,  $i-1$  being the last month for the calculation of the moving average.

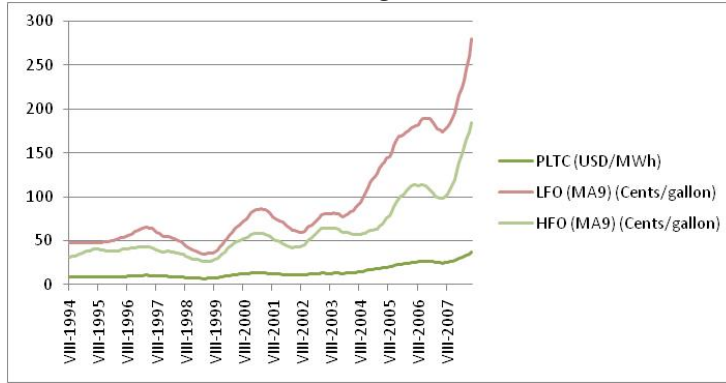
After substituting the left-hand side with Equation (ii) and dividing both sides by the exchange rate  $ER_{i-1}$  (CZK/USD), we receive the equation for  $P_{LTC}$  expressed in USD/MWh:

$$(2,5 + 0,36 * Brent_{MA9(i-1)}) = (P_0 + \alpha * HFO_{MAx(i-1)} + \beta * LFO_{MAy(i-1)} + u_i), \quad (v)$$

We want to find  $P_0, \alpha, \beta, x$  and  $y$ , which return the minimum least squared error. In the first step, we have identified a strong autocorrelation in residuals by the Durbin-Watson statistic. The problem is that original datasets and their moving averages are strongly autocorrelated.

<sup>12</sup> source: www.eru.cz.

Chart 2: Autocorrelation in the original time series



Source: Authors based on Brent, HFO and LFO data.

Thus we have transformed the averaged prices from Equation (v) into log-returns in the following way:

$$r_i = \ln\left(\frac{P_i}{P_{i-1}}\right) \tag{vi}$$

Where  $i$  again denotes time and  $P$  is the moving average of the price. Through this step we removed a part of the autocorrelation in residuals, but a residual autocorrelation still remained. The residual autocorrelation is caused by the fact that we are using moving averages. Therefore, we have used a Cochrane-Orcutt GLS estimator to obtain unbiased and efficient results. Results themselves are summarised in Table 2. The final model after the transformation of all variables into log-returns is:

$$\ln\left(\frac{P_{LTCi}}{P_{LTC(i-1)}}\right) = \lambda + \alpha * \ln\left(\frac{HFO_{MAxi}}{HFO_{MAx(i-1)}}\right) + \beta * \ln\left(\frac{LFO_{MAyi}}{LFO_{MAy(i-1)}}\right) + u_i \tag{vii}$$

Table 2: Regression results

Independent variable	Reference period of the moving average $x, y$	Regression coefficients $\alpha, \beta$	$\alpha, \beta$ significance (p-value)
LFO	6	0.191725	<0.001
HFO	9	0.47689	<0.001

Source: Authors

The regression  $R^2$  is 90.3%, which shows a strong relationship. Through further tests we cannot reject the normality in residuals and no further autocorrelation occurs. The estimated equation takes on the following form:

$$\ln\left(\frac{P_{LTCi}}{P_{LTC(i-1)}}\right) = 0.47689 * \ln\left(\frac{HFO_{MA9i}}{HFO_{MA9(i-1)}}\right) + 0.191725 * \ln\left(\frac{LFO_{MA6i}}{LFO_{MA6(i-1)}}\right) \quad (\text{viii})$$

Where

$HFO_{MA9i}$  is the HFO moving average of 9 previous calendar months expressed in Cents/gallon,  $i$ -being the last month for the calculation of the moving average,

$LFO_{MA6(i-1)}$  is the LFO moving average of 6 previous calendar months expressed in Cents/gallon,  $i$ - being the last month for the calculation of the moving average.

### **Interpretation of results**

We have analysed the dependency of the imported commodity price  $P_{LTC}$  on the price of light fuel oil and heavy fuel oil. We have found a strong relationship between the imported commodity price and the price of HFO and LFO (the regression  $R^2$  is 90.3%), where both coefficients for the LFO and HFO are strictly significant and positive, as we expected. The coefficient for the HFO is larger than that for the LFO, so we can state that the price development of  $P_{LTC}$  is more affected by the HFO. This is again a result that was intuitively expected because the HFO is more related to the oil itself. The intercept is insignificant.

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