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Price Convergence in German Natural Gas Markets

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Abstract

In 2007, Germany changed network access regulation in the natural gas sector and introduced a so called entry-exit system. While the number of balancing areas and corresponding wholesale trading hubs has been significantly reduced thereafter, its subsequent effect on price convergence as an indicator of market integration and competitiveness remains to be examined. We use cointegration analysis and a state space model with time-varying coefficients to study the development of natural gas spot prices in the two major entry-exit zones in Germany. To analyse information efficiency in more detail, the state space model is extended to an error correction model. Furthermore, we investigate price relations to the Dutch TTF which serves as a benchmark. Overall, our results suggest a fair price convergence between the corresponding market zones. However, allowing for time-variant adjustment processes, price differentials are only partly explained by transportation costs. Market efficiency decreased during the first half of the considered time period and has increased thereafter.

Keywords: natural gas market, regulation, cointegration, price convergence, time-varying coefficient

1. Introduction

The creation of an integrated natural gas market throughout Europe is one of the European Union's priority objectives. The introduction of the European Gas Directive (see 98/30/EC) and the EU 'Acceleration Directive' (see 2003/55/EC) have brought fundamental changes in the natural gas sector across many European countries. As such, the natural gas industries have been transformed from the vertically integrated monopolies to more competitive structures. While some countries have been relatively progressive in the liberalisation process such as the UK and the Netherlands, Germany opened its natural gas market effectively not until the EU directive 2003/55/EC had been transferred into the national law.

The German Energy Law (Energiewirtschaftsgesetz), introduced in July 2005, actually aimed at accelerating the process of market opening in the natural gas sector. The subsequent orders (mainly the Gasnetzzugangsverordnung) established a regulated network access based on an entry-exit system. As of October 2007, this new institutional design has become mandatory for all transmission network operators (TSOs) in the natural gas sector based on an agreement between the operators and the German energy regulator (Bundesnetzagentur).[1] The implementation of the entry-exit system has led to the establishment of different virtual trading points (hubs) in so called balancing zones or market areas for trading natural gas in Germany. In April 2009, the German government announced the aim of reducing the number of balancing entry-exit zones to one for H-gas and L-gas respectively,[2] covering all gas transmission networks (BMWi, 2009).

This paper evaluates the regulatory redesign in terms of its impact on German wholesale market development. Given the varying nature and patterns of trades at most of the trading hubs, it remains an open question whether a sufficient liquidity or a satisfactory degree of price convergence has been reached so far. Nonetheless, at two of the German hubs, NetConnect Germany (NCG) roughly covering the South of Germany and GASPOOL (GPL) covering Northern Germany, a functioning market for natural gas seems to have evolved. Whether these two sub-national markets are yet competitive remains to be empirically tested.

However, analysing the price convergence of the two German hubs might be misleading, as it neglects the possible importance of other connected European gas trading places. The Netherlands play a pivotal role in the natural gas market in continental Europe, for instance. Prices of natural gas across German markets are therefore compared to the Dutch Title

[1] In the first year after entering into force of the Gasnetzzugangsverordnung network operators had the choice between the introduction of the new entry-exit system and the retention of the old system based on path dependent network fees.

[2] H-gas is high caloric natural gas primarily delivered from Norway and Russia to Germany. L-gas is a low caloric natural gas and has a lesser energy content than H-gas. L-gas is imported from Netherlands to Germany.

Transfer Facility (TTF) hub which can be considered to be one of the most liquid wholesale gas trading hubs (Wood, 2008) in continental Europe besides Zeebrugge. So, the Dutch local gas trading place can serve as a (competitive) benchmark for the German natural gas spot market.

Competitive connected markets should show equal prices for a certain good (law of one price). Markets with a common price trend are said to be economically integrated. Given that market integration is a state as well as a process towards an economic equilibrium, we analyse the presence of a competitive and integrated natural gas market with open network access by studying the price convergence between different market areas. To test for price convergence, we use the Johansen method of cointegration analysis (Johansen, 1988). Due to the on-going changes of the regulatory framework in Europe and Germany, price convergence could also be a gradual and on-going process. An implicit assumption of cointegration analysis is that the structural relation among the prices is fixed over the considered time period. Therefore, we examine the convergence path of the natural gas spot market prices and the degree of market integration estimating a state space model using the Kalman filter which allows for time varying coefficients (Kalman, 1960). In contrast to cointegration analysis it is explicitly accounting for possible dynamic structural changes along the path towards market integration. Finally, the state space model is extended to an error correction model to judge how efficiently markets absorb new information (innovations). The time-varying nature of this approach allows us to draw conclusions how efficiency evolved over time and whether changes of the regulatory framework have led to improved market conditions. To the best of our knowledge, regarding natural gas markets no other study exists that uses a comparable approach and delivers similar insights. Therefore, our paper substantially extends the existing literature and, thus, contributes to the on-going discussions around the regulatory design of European natural gas markets.

The paper is structured as follows. Section two describes the institutional design of the German natural gas market. Section three discusses the previous literature involving the fixed and time varying structural relationships across different markets testing for price convergence and market integration. The econometric methodology is described in section four. Data is described in section five. Section six includes the estimation results and their interpretation. Finally, section seven concludes with potential policy recommendations.

2. Institutional Design and Recent Developments in Germany

In 2005, a new Energy Law (Energiewirtschaftsgesetz) has been enacted in Germany transferring the European Directive 2003/55/EC into national law. Its major purpose is to develop and establish competition in the German energy sector. Concerning third party access to the natural gas networks, a use of system charging regime based on simple entry and exit charges (entry-exit system) was declared to be installed. In October 2006, an agreement about the institutional design of that new regime between the transmission network operators and the Bundesnetzagentur was closed. Since October 1st 2007, the entry-exit system has become mandatory for all TSOs. The agreement initially divided Germany into 19 entry-exit zones (also called market areas or transmission system zones). Meanwhile, due to several poolings the number of zones has decreased to six, three for L-gas and three for H-gas (as of October 2009).[3] A major pooling has been the creation of NetConnect Germany (NCG) which has become operational on October 1st 2008 and combined the former areas of E.ON and Bayernets.[4] While NCG covers the South of Germany, GASPOOL as the second major market zone is located in the northern part of Germany.[5] The core of this area has already been established in 2006 with a co-operation between BEB[6], StatoilHydro and DONG Energy. In July 2008, Gasunie, operating the Dutch transmission network, has taken over the transportation services of BEB. The third market zone is run by RWE.[7]

The entry-exit system requires that the natural gas shippers book capacity at the relevant entry and exit points separately. Hence, the fees to be paid for the transportation of natural gas (so called entry and exit charges) should therefore no longer be based upon the distance between the entry and exit points (also known as the contractual path) as practiced in Germany, before. The abolition of such a 'path based' charging system was meant to promote price transparency as shippers need not obtain individual quotations for each separate customer, thereby reducing pricing complexity. Also, the trading possibilities at multiple hubs as a result of an entry-exit system should deliver a competitive price signal to the German natural gas market as a whole. It should facilitate both domestic as well as cross border transports for third parties thus encouraging market entry and eventually competition. Furthermore, the market redesign aims at increasing the flexibility and comfort in booking procedures as no

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[3] As low caloric gas plays only a minor role in Germany, our focus is solely on H-gas. Roughly speaking, each of the three market zones for H-gas, NCG, GASPOOL and RWE, also operates an L-gas network.

[4] Very recently, GRTgaz Deutschland, ENI and GVS joined NCG.

[5] GASPOOL has been established only very recently with ONTRAS and Wingas joining the cooperation of Gasunie, StatoilHydro and Dong Energy. Due to several renamings of this area over the considered period and to avoid confusion we use the current name GASPOOL of this market zone throughout the paper.

[6] BEB, owned by Shell and ExxonMobil, was one of the frontrunners as they introduced an entry-exit system already in 2004.

[7] In preparation of selling their transmission network, RWE handed over the assets to Thyssengas, a 100% subsidiary of RWE.

capacity reservation is required for individual pipeline sections used for the fulfilment of transport contracts. So, consumers and distributors were intended to benefit from increasing gas-to-gas competition as a result of entry-exit practice after gas market liberalisation.

The reform's economic success faces certain risks, however. A high number of market areas complicates market operations. Also, dominant players may continue to operate in the zones of their network operators affiliate[8] while new market entrants may be deterred. The transmission of natural gas via the network may become expensive due to pan-caking and also may be impossible due to congestion and grandfathered capacity rights held by the incumbents. Such market barriers could effectively rule out the aim of achieving competition and liquidity in the natural gas sector even with the introduction of the entry-exit regime.

3. Literature Review

Different studies have been carried out worldwide on natural gas markets integration and price convergence as an aftermath of market liberalisation. However, the methodology to account for market integration and price convergence differs across studies. Using cointegration analysis, Walls (1994), De Vany and Walls (1993, 1996) as well as Serletis (1997) found that the opening of network access in the aftermath of FERC Order 436 in 1985 led to greater market integration as prices across different locations converged in the North American natural gas markets. Likewise, King and Cuc (1996) examined the degree of pair wise price convergence using a time-varying parameter approach in the North American natural gas spot markets confirming the results of the cointegration analyses. Serletis and Rangel-Ruiz (2004) showed that the main driver for North American natural gas prices is the price trend at the Henry Hub. Applying a vector error correction model (VECM), Cuddington and Wang (2006) found different degrees of market integration across regions. While the East and Central regions are highly integrated, the Western market is only loosely connected to common price trends.

In the European context Asche et al. (2002) applied cointegration technique to test for the law of one price across the French, German and Belgian market using monthly natural gas import prices. Their results show an integrated gas market as prices across the considered regions follow a similar pattern over time. Using the Kalman filter, Neumann et al. (2006) study the price relation between the UK (National Balancing Point) and the Belgian spot market (Zeebrugge). They conclude the presence of a full convergence of prices between these two markets.

[8] In Germany, the network operators are legally unbundled but not in terms of ownership.

Further empirical studies in this context investigate price relations for natural gas either between different continents or between gas and other commodities for a certain region. Among the first group are e.g. Ripple (2001) Siliverstovs et al. (2005) and Neumann (2008). All studies find evidence for an increased price convergence across continents. The relation of gas prices to other commodities has been analysed quite extensively, e.g. by Asche et al. (2001) and Panagiotidis and Rutledge (2007) for the UK, and by Hartley et al. (2008), Brown and Yücel (2008) and Villar and Joutz (2006) for the US.

Now, the current study differs from the growing and already existing literature on natural gas price convergence and market integration in three ways. First, we analyse the implications of a new regulatory regime in Germany which is intended to foster competition by looking at the dynamic price interactions between two major German gas spot markets. Moreover, these price trends are put into a European context by relating them to the Dutch spot market. Second, not only cointegration analysis is applied and a time-varying coefficient approach estimated, but also the latter is extended to an error correction model. This allows us to draw conclusions on how efficiently new information is absorbed by the market and how this information efficiency evolved over time. Third, we explicitly control for transportation costs.

4. Econometric Methodology

The relationship between the natural gas spot prices at the three locations, GASPOOL (GPL), NetConnect Germany (NCG) and the Dutch Title Transfer Facility (TTF) hub will be evaluated pairwise in three steps. First, spot prices are adjusted for transmission charges. Second, cointegration analysis will be used in order to test if prices tend towards a common long-run equilibrium price. Results are used as a first indication whether markets are integrated or not. In the final step, a time-varying coefficient model is estimated using the Kalman filter to study price convergence over time.

4.1 Transmission Charges

Starting point of our analysis is the spatial no arbitrage condition for efficient markets that prices of identical products traded at regionally distinct locations should differ only in transaction costs (law of one price). Regarding natural gas markets transaction costs are mainly reflected by the charges shippers have to pay for gas transmission. Accounting for these transmission costs, arbitrage freeness for goods traded at different locations is assured if the price in the exporting region ($P_{i,t}$) plus cost for transmission ($TC_{i \rightarrow j,t}$) equals the price in the importing region ($P_{j,t}$).The spatial no arbitrage condition can be generalized as follows:

(1) $P_{j,t} - P_{i,t} \leq TC_{i\to j,t}$,

where equality holds only if trade between the two regions occurs. If the price differential is strictly less than the cost associated with gas transport, market participants have no incentive to trade. In an entry-exit regime these costs into one direction consist of the exit fee for the exporting region and the entry fee for the importing region. Concerning continental Europe, transmission charges are direction-specific, i.e. $TC_{i\to j} \neq TC_{j\to i}$. Due to this asymmetric characteristic, the arbitrage condition can be reformulated as:[9]

(1a) $P_{i,t} + d_{i\to j,t} \cdot TC_{i\to j,t} = P_{j,t} + d_{j\to i,t} \cdot TC_{j\to i,t}$,

$d_{i\to j,t} = 1$ if $P_{i,t} + TC_{i\to j,t} \leq P_{j,t}$ and $d_{i\to j,t} = 0$ otherwise;

$d_{j\to i,t} = 1$ if $P_{j,t} + TC_{j\to i,t} \leq P_{i,t}$ and $d_{j\to i,t} = 0$ otherwise;

i,j = GPL, NCG, TTF.

Physical gas flows are only possible into one direction at the same time. As no information about the actual flows between the considered regions has been available, we include a dummy variable d mapping these flows. The dummies allow determining the relevant transmission costs depending on the actual price differential. It should be noted that both dummies can be zero at the same time, but never unity. The former situation prevails if spot price differentials are too low to exceed the difference in transmission charges. Trading gas between the two regions would be unprofitable. Therefore, this setting tends to slightly overestimate the true price convergence.

With $P_{i,t}^{net} = P_{i,t} + d_{i\to j,t} \cdot TC_{i\to j,t}$ as the transmission charges adjusted spot price and using log prices ($p_{i,t}^{net} = \log(P_{i,t}^{net})$), equation (1a) becomes

(1b) $p_{i,t}^{net} = p_{j,t}^{net}$,

i,j = GPL, NCG, TTF.

If this condition is violated, markets are neither fully competitive nor integrated. However, real world complexities in trading imply that several factors may exist leading to deviations from this condition. The hypothesis to be tested is that the establishment of an entry-exit system has removed some of these reasons for inefficiencies, and thus, prices converged during the considered time period.

4.2 Cointegration Tests

[9] With this approach, we modified a model suggested by Zachmann (2008) who analysed convergence of European electricity spot prices controlling for the outcome of capacity auctions.

A precondition for cointegration analysis is that the considered time series have a unit root. Therefore, we test for unit root using the Augmented Dickey Fuller (ADF, Dickey and Fuller 1979) and the Kwiatkowski Phillips Schmidt and Shin (KPSS, Kwiatkowski et al. 1992) tests. While ADF is based upon the null hypothesis of a unit root, the KPSS is based upon the null hypothesis of stationarity. The setting reduces the problem that unit root tests sometimes face the problem of poor power properties.
Applying the Johansen test (Johansen 1988, 1995) to natural gas spot price series of two regions, one expects exactly one contegrating relation if these regions belong to the same market. The corresponding two dimensional vector error correction (VEC) model is:

$$(2) \qquad \Delta p_t^{net} = \Pi p_{t-1}^{net} + \sum_{k=1}^{l-1} \Gamma_k \Delta p_{t-k}^{net} + \varepsilon_t \; ;$$

where Δ is the first difference operator, p_t^{net} is the vector of the two spot prices, $\varepsilon_t \sim n.i.i.d.(0,\Sigma)$, Π is a (2×2) matrix of the form $\Pi = \alpha\beta'$, with β comprising the cointegrating vector and α representing the corresponding loadings. While β coefficients show the long-run equilibrium relationship between price levels, α coefficients measure the adjustment speed toward the equilibrium.
According to equation (1b), we expect $\beta = [1,-1]$. In order to control for transaction costs not reflected in the transmissions fees, we allow for a constant in the cointegrating relation. However, if the law of one price holds, this constant should be close to zero.
The Johansen approach assumes a constant cointegrating vector over time. As pointed out by several studies, e.g. King and Cuc (1996), Kleit (2001) and Li (2008), the cointegration relationship does not shed any light on the dynamics of possible price convergence or divergence. Especially, against the background of the dynamic regulatory framework in Europe as pointed out earlier, the assumption of a fixed relationship between spot prices over time might be problematic. Following the line of argument of Baulch (1997a, 1997b), Barrett (1996) as well as Barrett and Li (2002), results from cointegration are only used as a kind of pre-test whether markets are integrated or not. The closer β is to one, the better integrated the markets are.

4.3 Time-varying Coefficient Model

A model approach with time-varying coefficients can overcome these drawbacks and account for the dynamics of parallel price developments from regionally distinct markets. The introduction of a time-varying coefficient into the linear relationship of prices allows us to analyse the path of price convergence or divergence.

Recalling equation (1b) and introducing a constant c_{ij}, again reflecting costs associated with trades between the two regions and not already covered by transmission charges, we can formulate the following state space model

(3) $$\begin{aligned} p_{i,t}^{net} &= c_{ij} + \beta_t \cdot p_{j,t}^{net} + \varepsilon_t \\ \beta_t &= \beta_{t-1} + \upsilon_t \end{aligned},$$

where $\varepsilon_t \sim N.i.i.d.(0, \sigma_\varepsilon^2)$ and $\upsilon_t \sim N.i.i.d.(0, \sigma_\upsilon^2)$ are white noise processes and β_t is the vector of unobservable coefficients at time t.

β_t represents the strength of price convergence across regions. If $\beta_t = 0$, it implies that there is no relation between the natural gas spot prices such that the markets are completely decoupled. If price convergence is occurring and markets are perfectly integrated and competitive, β_t should be equal to one. Furthermore, as prices ($p_{i,t}^{net}$) are already adjusted for transportation costs, we expect c_{ij} to be negligible. Otherwise, in addition to the transportation charges significant other costs would be present in the market preventing shippers from trading and, therefore, prices from converging. These costs put a constant gap between the considered price series and might be an indication for permanent capacity constraints that might be due to either technical or contractual reasons. While the former is just a sign of underinvestment, the latter points at hoarding of capacity rights[10] by incumbents signalling the abuse of market power and should be tackled by the regulator.

The state space model is estimated using the Kalman filter.[11] This technique processes the whole data on both price series in two consecutive steps. It first estimates β_t by using available information till the period t-1. In a second step, the estimates of β_t are updated by incorporating prediction errors from the first step as information at time t is realized. So, using the Kalman filter will enable us to obtain detailed information on the trends contained within the price series. It provides information for β_t and c_{ij} for each point in time.

Finally, we use the framework of time-varying coefficients to formulate an error correction model in the following way:

(4) $$\begin{aligned} \Delta p_{i,t}^{net} &= c_{ij} + \alpha_t (p_{i,t-1}^{net} - p_{j,t-1}^{net}) + \varepsilon_t \\ \alpha_t &= \alpha_{t-1} + \upsilon_t \end{aligned},$$

[10] Transmission capacity is often booked very long in advance and has to be nominated when shippers actually want to use it. Hoarding of capacity rights just means unused capacity which is not available for other market participants.

[11] For further details see Harvey (1989). We use EViews 6.

where α_t measures the time it takes to bring the system back towards equilibrium after new information entered the market. The larger the absolute value for α_t, the higher the speed of price adjustment and the more efficiently innovations are converted into price signals. Therefore, the time-varying framework enables us to draw conclusions not only on how efficiently information has been absorbed by the market, but also how efficiency evolved over time. Since the entry-exit regime has been introduced in order to ease gas transmission and foster gas-to-gas competition, we expect the absolute value of α_t to increase over time.

5. Data

The aim of this paper is to test for market integration and price convergence between the major two entry-exit zones in Germany, namely GPL and NCG. Additionally we check for price relations with respect to the Dutch trading hub TTF which has well established trade connections with Germany and is a major European gas trading point. For the German trading hubs, we have used the day-ahead spot market settlement price for natural gas as publicly obtained from the European Energy Exchange (EEX) while for TTF the data has been obtained from Energate. The day-ahead data price is preferred to using weekly or monthly price data so as to portray the current institutional and infrastructural conditions in the markets being studied. Taylor (2001) argues that using lower frequency data (such as monthly or yearly) to study the price adjustment process can lead to temporal aggregation problems. So, the use of high frequency recent data should capture the reactions to ongoing regulatory and market reforms, thereby facilitating in the study to examine market integration. The timeframe for the data used in this study dates from 1st of October, 2007 when the mandatory introduction of the entry-exit system came into operation to the 30th of September, 2009.[12] The prices have been transformed into logarithmic form as the spot market prices for natural gas tend to be highly volatile and may be potentially heteroscedastic in nature.

[12] Any price data for both German market areas prior to October 2007 hardly exist and face the problem of low reliability. The considered time period covers two so called "gas years", starting with the heating season in October and ending in September. For each price series this results in 494 observations.

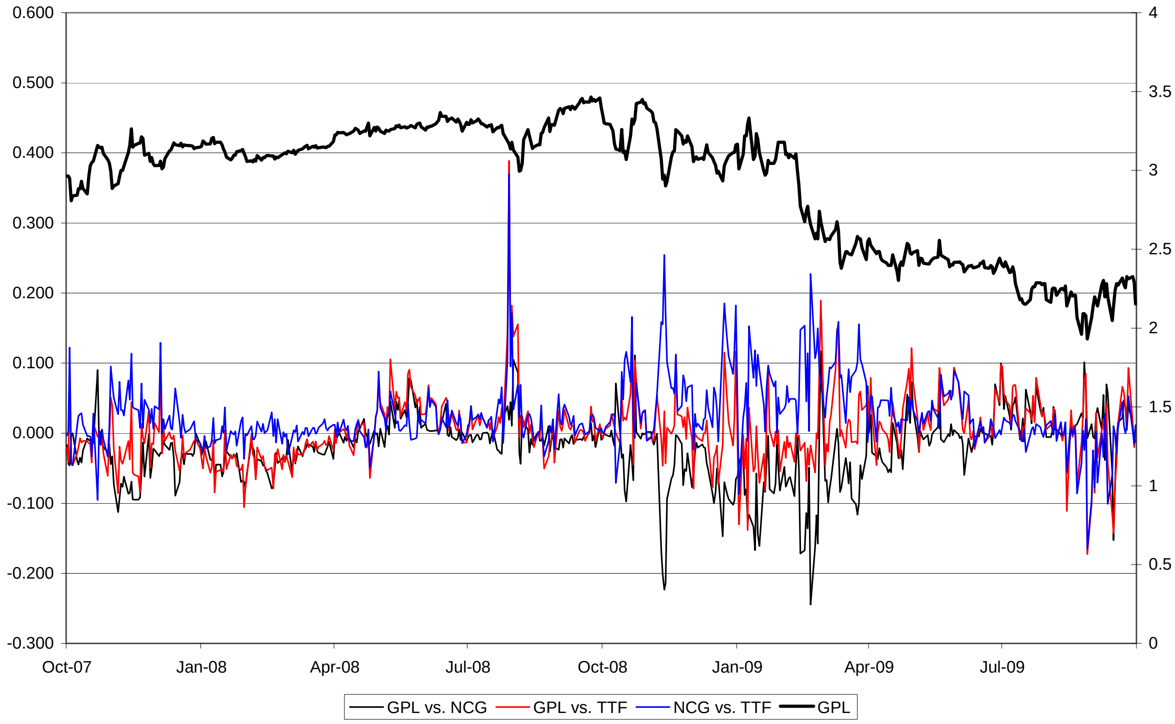

Figure 1: Logarithmic day-ahead spot prices (€/MWh)

Notes:
Right Y-axis: Log spot prices for GPL
Left Y-axis: Differential of log prices for GPL vs. NCG (black line), GPL vs. TTF (red line) and NCG vs. TTF (blue line).

It can be seen from Figure 1 that the day-ahead prices for natural gas were volatile throughout the considered time period for all market areas. The prices became more volatile during the last quarter of 2007 while the volatility moderated from the first quarter of 2008 till the third quarter of 2008. Prices then peaked across market areas with immense volatility while the first quarter of 2009 also witnessed a steep decline in the natural gas prices. The decline is likely – at least to some extent - due to the falling prices for crude oil as gas prices in mainland Europe are often index-linked to that of crude oil with some time lag.[13] Looking at the price differentials for the three considered pairs of market zones, no persistent price divergence becomes obvious. The development of price differentials roughly parallels the development of price volatility; the higher the volatility, the larger the magnitude of the observed gaps. Prices at NCG are most of the time slightly higher than at TTF and GPL.[14] All in all, price series

[13] While the price for Brent peaked on 3rd of July, 2008, GPL prices reached their maximum on 23rd of September 2008. NCG and TTF prices had their peak both on the 17th of September, 2008. This amounts to a lag of roughly two and a half months.
[14] For roughly 75% of the observations NCG prices lie above spot prices at GPL and TTF. Consequently, this ratio for GPL and TTF is 50%.

show a rather similar development over time[15] leading to the expectation of highly integrated markets, and thus values of the coefficient β in equations (2) and (3) close to one.

Information on transmission charges was obtained from the websites of the relevant TSOs as well as by personal contact to shippers.[16] For each possible relation between the three considered regions a representative connecting point has been chosen. To get consistent data, the corresponding capacity-based entry and exit charges expressed in [€/(kWh/h)/a] are converted into [€/MWh]. We assume that a transport of one MWh of natural gas corresponds to holding a capacity of one €/(kWh/h)/d. Since charges at GPL are expressed in [€/(m^3/h)/a], the referenced gas quality has additionally taken into account. Each TSO has changed their fees at different points in time. The resulting development of transmission charges over the considered time period is summarised in Table 1. While cost for transporting natural gas within Germany has decreased quite substantially (by about 10%), fees for cross-boarder transmission remained more or less the same.

Table 1: Transmission Charges

Direction of Transport	Connecting Point	Transmission Charges [€/MWh]				
		01/09/2007	*01/10/2008*	*08/12/2008*	*01/04/2009*	*01/07/2009*
GPL → NCG	Bunder Tief	0.557	0.523	0.512	0.497	0.497
NCG → GPL		0.619	0.582	0.565	0.534	0.534
GPL → TTF	Oude Statenzijl	0.420	0.420	0.420	0.410	0.400
TTF → GPL		0.409	0.409	0.409	0.394	0.408
NCG → TTF	Bocholtz	0.387	0.399	0.386	0.386	0.398
TTF → NCG		0.486	0.498	0.484	0.484	0.490

6: Results

To answer the question if the introduction of an entry-exit regime has led to more competitive market conditions, first we present the results of the contegration analysis followed by the outcomes of the time-varying coefficient approaches.[17]

6.1 Cointegration

[15] This is confirmed by the descriptive statistics which are not reported here but are available from the authors upon request. E.g., the standard deviation as a proxy for volatility is around 0.40 €/MWh (in log terms) for all three regions.

[16] Due to the ongoing reorganisation of the German TSOs and market zones historical data on transmission charges is hardly publicly available.

[17] A comparison of the situations before and after this new regulatory framework has been established would be preferable. This is not possible due to the lack of available price data for the German market zones prior to the introduction of the entry-exit regime. Nevertheless, market outcomes after the new system has become operational allow us to draw conclusions about the effectiveness of the new regulation.

To check whether the price series fulfil the precondition for cointegration analysis, we test for unit root. The results from both ADF and KPSS, displayed in Table 2, provide a clear picture. All time series have a unit root and are I(1) as first differences are stationary.

Table 2: Unit Root Tests

Natural Gas Spot Prices (log)				
Region	**ADF**		**KPSS**	
	Level	**First difference**	**Level**	**First difference**
GPL	-1.012	-21.353***	1.950***	0.182
NCG	-0.852	-23.738***	1.926***	0.231
TTF	-0.949	-23.034***	2.005***	0.210

Notes: Tests include a constant but not a time trend. For ADF, the lag length is selected according to Schwarz Information Criterion (SIC). For KPSS, bandwidth has been chosen according to Newey-West using the Bartlett Kernel. The provided numbers denote the t-ratios for ADF and the LM statistic for KPSS.
*, **, *** indicate significance at the 10, 5 and 1 %-levels.

Next, Equation (2) is evaluated using the approach developed by Johansen (1988, 1995). Each pairwise price relation has exactly one cointegrating term indicating that long-run equilibria do exist.[18] Price series share a common stochastic trend and hence will not drift apart largely in the long run. Table 3 contains the main results of the corresponding VEC models.

Table 3: Long-run Cointegrating Equations (ML Estimation)

Region	**Cointegrating Equation**				**LR Test**	
	β	α		Constant	$\beta = [1,-1]$	$\alpha = 0$
GPL-NCG	-0.983*** (0.010)	GPL	-0.155** (0.076)	-0.038 (0.028)	3.071*	4.115**
		NCG	0.158** (0.073)			4.581**
GPL-TTF	-0.997*** (0.007)	GPL	-0.332*** (0.064)	-0.014 (0.021)	0.227	26.049***
		TTF	0.188*** (0.064)			8.343***
NCG-TTF	-1.011*** (0.010)	NCG	-0.342*** (0.076)	0.0166 (0.030)	1.328	19.470***
		TTF	0.025 (0.076)			0.106

Notes: Lag length to map short-run dynamics selected according the Schwarz Criterion using an unrestricted VAR. Number in brackets report standard errors. Numbers for the LR test denote the χ^2-statistics.
*, **, *** indicate significance at the 10, 5 and 1 %-levels.

[18] Both unrestricted cointegration rank tests, Trace as well as Maximum Eigenvalue, lead to equivalent results.

All β coefficients are very close to one. The likelihood ratio test in the last but one column of Table 3 tests for the restriction of the cointegrating vector being $\beta = [1,-1]$, meaning that a 1% price change in region i is accompanied by the same price change in the other region. Only in the case of the two German areas this indication of very strong market integration has to be rejected at a 10% level. The insignificant constant in the long-run cointegrating equation signals that no other significant transaction costs in addition to the already captured transmission charges exist. Looking at the error correction coefficient α we see significant bi-directional price adjustments for GPL-NCG and GPL-TTF. The relationship of natural gas spot prices between GPL and TTF is stronger since the level of significance and adjustment speed are higher. While for GPL-NCG it takes around 6 ($1/\alpha$) trading days to bring prices back to equilibrium, GPL prices adjust within 3 days to an imbalance with TTF prices. The stronger interconnection between GPL and TTF might be due to the fact that both networks are now run by the same TSO, Gasunie. The asymmetric price adjustment in the latter case with GPL prices adjusting faster than TTF prices indicates that TTF as the larger and more liquid market is the leading market for GPL. The same argument holds for the NCG-TTF results with only NCG adjusting to deviations from equilibrium. A likelihood ratio test restricting α_{TTF} to zero confirms that TTF is weakly exogenous for NCG. These results support the hypothesis that the Dutch TTF can be considered as a kind of reference or leading market for both German market areas.

To sum up, results from cointegration analysis provide evidence of market integration through price convergence across the two German market areas considered in this study. But, one has to interpret these results with care. The presence of cointegration does not necessarily imply the stability of the estimated β parameter. The long run β coefficient may not stay constant over time as several structural changes have occurred in the natural gas markets. Hence, it is essential to test for the stability of the estimated parameter for the considered time period.

6.2 Time-varying Coefficient

The time-varying coefficient approach particularly accounts for these structural changes. Table 4 presents the main results of the analysis of market integration through price convergence (Equation 3) as well as the outcomes of the error correction model (Equation 4) which gives insights into the information efficiency.

In the final state, GPL and NCG show the highest degree of price convergence (0.943) but the lowest speed to adjust for innovations. This means that highly integrated markets are not necessarily the most efficient markets. Comparing the results with the previous cointegration analysis, what is most striking is the significance of the constant in all three estimations of Equation (3). Allowing for a time-varying specification discloses a price differential present in the market that goes beyond pure transmission charges. The largest additional price gap is observed between NCG and TTF, nearly twice as high as in the other two cases. This gap is most likely caused by capacity constraints, thus indicating an additional scarcity. As one of the major complaints concerning the natural gas market - raised not only by newcomers but also by energy regulators - is the insufficient amount of transmission capacity available to market participants, the result of the state space approach is much more consistent with market observations than the one of cointegration analysis in the previous sub-section.[19] Due to the assumption of constant price relations over the considered period, the VECM is unable to reveal this finding. In fact, the averaging characteristic of cointegration analysis may lead to overestimated degrees of market integration.

Table 4: Results of the Time-varying Coefficient Models

Region	**Price Convergence [Equation (3)]**		**Information Efficiency [Equation (4)]**	
	β	Constant	α	Constant
GPL-NCG	0.943*** (0.007)	0.157*** (0.042)	-0.516** (0.225)	-0.002 (0.003)
GPL-TTF	0.919*** (0.005)	0.173*** (0.036)	-0.825*** (0.206)	-0.001 (0.002)
NCG-TTF	0.879*** (0.006)	0.271*** (0.036)	-0.633*** (0.217)	0.006** (0.003)

Notes: For the coefficients the final state is provided. Numbers in brackets report the root mean square error for the coefficients and standard errors for the constant.
*, **, *** indicate significance at the 10, 5 and 1 %-levels.

Figure 2 shows the development of the β coefficients over time. All three pairs of market zones already started with a rather high degree of price convergence (above 0.91) that slightly increased during the first year after the introduction of the entry-exit regime in October 2007. The price gap for GPL-NCG and GPL-TTF not explained by transmission charges started to increase (decrease of the β coefficients) during the third quarter of 2008 which coincides with the takeover of BEB by Gasunie. At the end of the period both pairs more or less has dropped back the initial level. Concerning prices at NCG and TTF, a plunge of the β coefficient can be

[19] The issue of available transmission capacity is raised in rather any of the existing monitoring reports. Hardly existent secondary markets for unused capacity rights amplify this problem. Therefore, the German Ministry of Economics and Technology plans to revise the order dealing with network access (Gasnetzzugangsverordnung). The intention is to enforce shippers to market unused capacity rights.

observed right after the common market area operation between E.ON and Bayernets. These results are quite astonishing as both events were expected to improve market performance.[20]

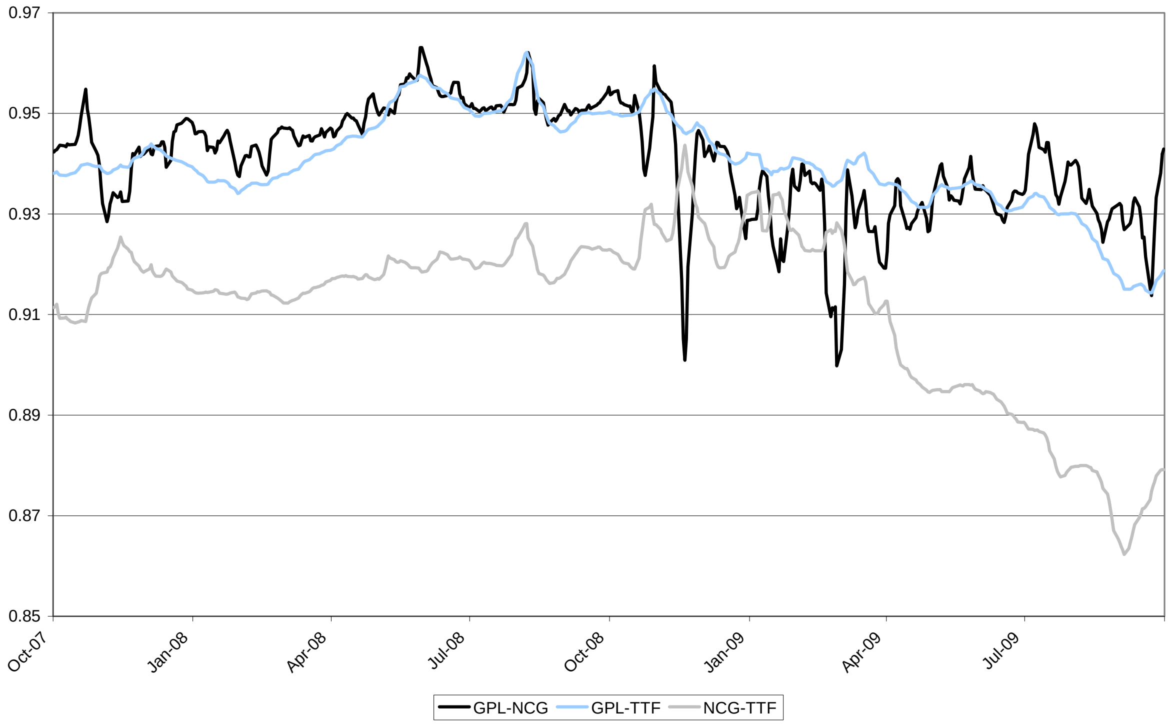

Figure 2: Price Convergence (β)

The development of information efficiency is depicted in Figure 3. The coefficient α of the error correction model of Equation (4) indicates how fast prices turn back to equilibrium once new information has entered the market. The higher the absolute value of α, the faster innovations are absorbed by the market and the more efficient markets are. The price relation between GPL and NCG shows the lowest efficiency throughout the whole period.

[20] One might argue that the formations of the β coefficients are mainly explained by the oil price movement as a common exogenous factor driving the gas prices. This argument seems to be implausible, since the decline of price convergence between NCG and TTF started later than in the other two cases. Furthermore, the oil price has increased already since beginning of 2009. Taking into account the time lag of roughly 2.5 months β should have envisaged an upswing during the second quarter of 2009.

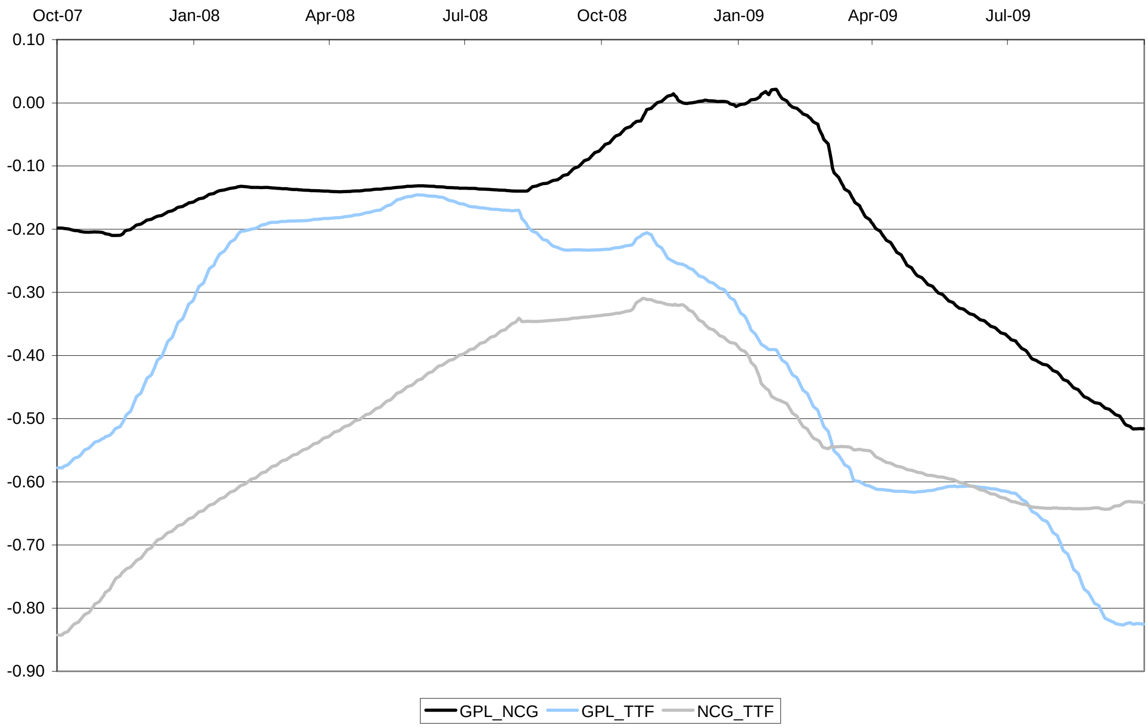

Figure 3: Information Efficiency (α)

7. Conclusions and Policy Implications

The aim of this paper was to study the development of market integration after the introduction of the entry-exit network pricing regime in the natural gas markets in Germany. Therefore, we applied the Johansson cointegration test and Kalman filter estimation to test for price convergence. The results suggest converging prices convergence between two major market areas in Germany. Our Results also show that the market integration of GUD with the Dutch TTF makes GPL a relatively more competitive trading hub than NCG. So, the German regulatory quest of achieving full market integration by developing a single large entry-exit zone covering all gas networks seems to be achievable also with the existence of two German hubs. The final effect of such full market integration could be a robust and competitive market for natural gas.

However, these results should not be interpreted as a first best economic situation. This is because our study only analyses the prices at the two major trading hubs while the German gas market is still fragmented. The wholesale market still seems to lack liquidity, the number of market participants might still be too low. One important reason could be blocked or congested transportation capacity. Hence, gas transportation networks have to be regulated and market rules have to be set. Thus, implementing incentive regulation in the natural gas transmission from the beginning of 2009 as well as a further development towards a competitive gas storage market should help in creating a competitive wholesale market for natural gas. Also, establishing effective and transparent rules concerning entitlements to open network access for third parties is and stays necessary in order to benefit from a fully liberalized market in Germany.

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