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Convergence of European Spot Market Prices for Natural Gas?

A Real-Time Analysis of Market Integration using the Kalman Filter

ANNE NEUMANN

BORISS SILIVERSTOVS

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Address of the author(s):

Anne Neumann
Dresden University of Technology
Dpt. of Business Management and Economics
DREWAG-Chair of Energy Economics
01062 Dresden
Germany

e-mail : anne.neumann2@mailbox.tu-dresden.de

Boriss Siliverstovs
DIW Berlin (German Institute for Economic Research)
Dpt. International Economics
Koenigin-Luise-Str. 5
14195 Berlin
Germany

e-mail : bsiliverstovs@diw.de

Editors:

Faculty of Business Management and Economics, Department of Economics

Internet:

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Dominik Maltritz
e-mail: wpeconomics@mailbox.tu-dresden.de

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Anne Neumann
Dresden University of Technology
Dpt. of Business Management and Economics
01062 Dresden
anne.neumann2@mailbox.tu-dresden.de

Boriss Siliverstovs
DIW Berlin (German Institute for Economic Research)
Dpt. International Economics
14195 Berlin
bsiliverstovs@diw.de

Abstract:

This paper provides a textbook example of integration between commodity markets, and the subsequent price convergence or absence thereof. We analyze price relations between spot markets for natural gas in Europe. We apply time-varying coefficient estimation applying the Kalman filter, to test whether price convergence between different locations is really taking place. Our results reveal that the construction of a pipeline between the UK and Zeebrugge (Belgium) has led to almost perfect price convergence between these locations; on the other hand, liberalization on the continent does not seem to be working yet.

JEL-Classification: C32, L95, D43, Q49

Keywords: integration, convergence, econometrics, natural gas

INTRODUCTION

Since the seminal work of Engle and Granger (1987) on cointegration methodology, a number of sectors have been tested for common movement between price series assuming a fixed structural relationship of variables over time (short- and/or long-run dynamics). The difference of two complementary but very distinct concepts to investigate shared trends in multivariate time series is the assumption of either a static or a dynamic structural relationship between considered variables. Johansen (1995) provided a different (multivariate) approach to the same concept with the possibility of hypothesis testing on cointegration vectors. Already in the early 1980s, Harvey (1981) proposed the concept of convergence of time series under scrutiny. Convergence has been treated extensively since, e.g. in the context of European financial integration. The obvious relationship of Dollar and Deutschmark within the European Community was the reason for Haldane and Hall (1991) to measure temporal bivariate relationships of three exchange rates using time varying parameters. Serletis and King (1997) conclude that EU stock markets have converged under between 1971 and 1992, but that this process had not reached the final state. Bekaert and Campbell (1995) were the first to apply a time varying approach to measure capital market integration of markets exhibiting time-varying market integration. Based on the Hamilton approach (1989, 1990) they introduce a state variable following a Markov process allowing for different market-regimes.

Natural gas markets have attracted a fair amount of research on integration and convergence thus far, in particular in connection with liberalization. For North America, the literature suggests that opening of network access led to convergence of prices in different locations: natural gas markets exhibit strong evidence of integration since FERC order 436 issued in the year 1985 (De Vany and Walls, 1995; Walls, 1994; Serletis, 1994). Works of King and Cuc (1996) as well as Cuddington and Wang (2004) use time-varying coefficient estimation and autoregressive models of price differentials, respectively, to detect convergence of spot prices in the US. For Europe, the only analysis of that type was carried out by Asche, Osmundsen, and Tveteras (2001, 2002) suggesting an increasing level of integration of European natural gas prices at the country level.

The EU Directive on natural gas market liberalization (98/30/EC) has propelled Europe among the liberalizing markets as well, and public and private interest in the integration of formerly nationally-oriented natural gas markets is increasing. This paper carries the analysis a step further, as it is the first to analyze the relation between spot markets for natural gas in Europe. In the event of liberalization, several market places, so-called "hubs", have in fact emerged, such as the National Balancing Point (NBP) in the UK, Zeebrugge in Belgium, and Bunde/Oude at the German-Dutch border. The relevant policy question is whether this process has lead to a convergence between prices at these different locations.

The remainder of this paper is organized in the following way: Section 2 sketches out the institutional context for natural gas trading in Europe and recent developments likely to foster price convergence. Section 3 discusses the economic theory and the econometric approaches to test for convergence. We apply a state-space formulation of a dynamic model and a specific optimization algorithm, the Kalman Filter. The data used are daily day-ahead prices for natural gas in the UK, Belgium, and Germany. Section 4 provides the results for the basic model and interprets them: the construction of a pipeline between the UK and Zeebrugge (Belgium) has led to almost perfect price convergence between theses locations. On the other hand, liberalization on the continent does not seem to be working as indicated by the low degree of convergence between the prices at Zeebrugge and Bunde (North West Germany). Section 5 discusses policy implications and concludes.

1. THE EUROPEAN NATURAL GAS MARKET AND THE INTERCONNECTOR

Natural gas generally is transported over long distances from producer countries (such as Norway or Russia) into the EU consuming countries. The EU Directive 98/30/EC ended the monopolistic market structure with pre-defined concession areas and the proprietary use of the pipeline by the vertically integrated natural gas transportation and trading companies (such as Gaz de France, Ruhrgas, etc.). The objective of the European Commission was to break up the national monopolies by abandoning the concessions and allowing third parties, i.e. trading companies, to obtain non-discriminatory access to the transmission grid. Thus an integrated single European market should be created.

However, the results of liberalization have been mixed thus far. Whereas the UK has succeeded in setting up a competitive market, many continental European countries have not. The EU Benchmarking Reports regularly criticize the little progress in constructing the single European natural gas market (e.g. European Commission, 2005).

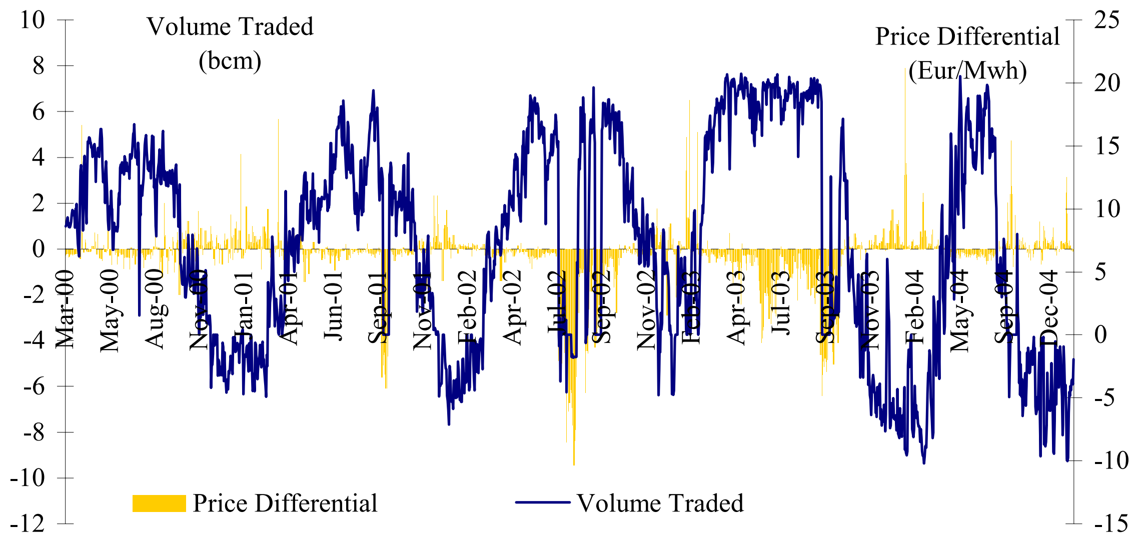
Therefore, another directive was implemented in 2003 to accelerate the reform process in the natural gas industry (so-called "acceleration directive", 2003/55/EC). Our analysis should provide a quantitative assessment of the attempts to liberalize.

In the late 1990s, a path breaking development took place: The liberalized UK market was connected with the non-liberalized Continental European market through a pipeline, the so-called "Interconnector". Nine trading and transmission companies had made long term capacity commitments amounting to 20 bcm per year giving obvious reasons for the creation of the first physical connection between the UK and the continent. Shareholders in the Interconnector signed export contracts for more than half of the potential exports through the Interconnector. The landing point at Zeebrugge coincides with the landfall for Norway' s Zeepipe gas trunkline from the North Sea, with pipelines from the (Algerian) LNG chain and annual Troll deliveries to France. The hub at Zeebrugge is connected to the Belgian high calorific gas grid as well as to the gas networks in the Netherlands, in Germany, and in France.

Figure 1 shows the volumes of natural gas traded in the Interconnector, and the price differentials between the UK and Zeebrugge. During the winter season, prices in the UK are significantly above Zeebrugge hub prices reflecting short-term marginality of sources in Britain. In contrast, during the summer months, natural gas flows from the UK to the continent. The UK market is liquid in the sense of a mature spot market with a churning point of 15 (gas is traded about 15 times at the NBP before a physical flow takes place). The most mature and liquid Continental European spot market is situated at the far end in Zeebrugge, Belgium. Both locations provide open access to spot (and forward) markets with assumingly competitive pricing of natural gas. Furthermore, there are no rigidities in the operation of the Interconnector and its capacity is large enough to allow for a significant volume of trade.

In addition to the NBP and Zeebrugge, another trading place was set up on the continent: <u>Bunde</u> (German-Dutch border), where gas from Norway is landed. Thus, in 2004, there were three spot markets, with the pair NBP-Zeebrugge being connected through pipelines. The question to be investigated is whether price convergence has really taken place, in the spirit of the EU Directive and of economic theory.[1]

Figure 1: Traded volumes in Interconnector and price differentials NBP and Zeebrugge



2. THEORY: CONVERGENCE AND THE KALMAN FILTER

Arbitrage leads to the convergence of prices in two markets until the difference reflects only transaction costs including the cost of transportation. For complete convergence to take place, competitive and liquid markets at both markets are required. When analyzing relationships between prices, the price of the good in market *j* (P_j) can be expressed as a function of the price in market *i* (P_i) and of α_{ij} capturing transaction and/or transportation costs between the markets:

$$P_{j,t} = \alpha_{ij} + P_{it} \tag{1}$$

In order to analyze the relationship between different prices, the Kalman filter can be applied to pairs of (daily) price data where the resulting time-varying coefficient $\beta_{ij,\,t}$ is an indicator of the strength of the pricing relationship. Hence, it provides a powerful tool for estimation of the unobserved component in multi- or univariate structural time series models. In a first step, consider equation (1) in a regression framework where an element of time is introduced.

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[1] Note that a fourth trading hub has been set up recently in the Netherlands, the Title Transfer Facility (TTF). However, data on it is not sufficiently available yet.

$$P_{j,t} = \alpha_{ij} + \beta_{ij,t} P_{it} + \varepsilon_t \tag{2}$$

where ε_t is a random error term with zero mean and covariance matrix H_t. The law of one price (LOP)[2] holds for β_{ij} = 1 (at any time t) implying constant relative prices, whereas for β_{ij} = 0 no relationship between prices at any time *t* exists. According to King and Cuc (1996), strong convergence would be the case where differences between P_i and P_j converged for all *i* and *j*, whereas weak convergence would be convergence for only some *i* and *j*.

As the capacity of the Interconnector and institutional framework of access to it remain constant over the period under consideration, the coefficient α_{ij} does not seem to vary over time and is included as a time-invariant constant. Equation (3) is the transition equation

$$\beta_{k,t} = \beta_{k,t-1} + \mu_t \qquad k = 1,2 \tag{3}$$

with μ_t as an error term with mean zero and covariance matrix Q_t. Combined, equations (2) and (3) reflect the state space form of our approach. In addition, we include a dummy variable s(t)

$$s(t) = \begin{cases} 1 & & forward \\ -1 & if & reverse \quad flow \\ 0 & & no \end{cases} \tag{4}$$

in order to allow for discrepancy in a possible arbitrage relationship depending on the gas flow direction of the underlying transport infrastructure. It reflects the *actual flow direction* but not price differentials which would economically require a switch of the flow direction. In the Interconnector, gas mainly flows from the UK to continental Europe. Only in around one fourth of our observations, the flows had the reverse direction (cf. Section 4.1)

Thus, the *measurement equation* of the pricing relationship investigated can be represented as follows:

$$P_{j,t} = \beta_{1,t} P_{it} + \beta_{2,t} s(t) + \varepsilon_t \tag{5}$$

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[2] The law of one price states that in competitive markets free of transportation costs and official barriers to trade, identical goods sold in different countries must sell for the same price when their prices are expressed in terms of the same currency (Krugman and Obstfeld, 2003).

Costs for transportation and transactions are accounted for in $\beta_{2,t}$. When analyzing the relationship of continental European prices (Zeebrugge and Bunde), equation (5) is adjusted and becomes

$$P_{j,t} = \beta_{1,t} P_{it} + \alpha_{ij} + \varepsilon_t \qquad (6)$$

due to the lack of direct interconnection of the trading places.

The recursive procedure of the Kalman Filter first estimates $\beta_{i,t}$ using information up to $t-1$. In the following step, information at time t is realized and estimates of $\beta_{i,t}$ are updated using this information. We directly employ Bayes' s theorem stating that the probability of occurrence of an event A is conditional on the occurrence of event B. Providing the procedure with initial conditions delivers optimal estimators of the state vector as each new observation becomes available. The filter repeats these steps sequentially until all observations have been utilized. Summarizing, the Kalman filter uses prediction and updating equations to compute optimal estimates of the state variables based on all information available at time t using maximum likelihood estimations minimizing the mean square errors of $\beta_{i,t}$.[3]

4. DATA, ESTIMATION AND RESULTS

4.1 DATA

We use daily day-ahead bid prices of natural gas (as reported by Heren Ltd.) at the trading hubs NBP, Zeebrugge, and Bunde in Europe. The period under observation is from March 2000 until February 2005. This provides 1645 observations for the price pair NBP and Zeebrugge, and 705 observations for Zeebrugge-Bunde. Table 1 provides a summary of the descriptive statistics. Striking evidence for market liquidity can be gained by comparing some standard statistics such as maximal and minimal values of all time series. Volatility in prices reported from the NBP is highest whereas mean values do not differ significantly. Zeebrugge and Bunde exhibit a lower price limit of less than 6 Euros per MWh; on the contrary, the minimum for the UK is 1.86 Euros/MWh. This can be explained by market forces and extensive spot trading determining prices in the British gas market. Overall, distribution of all three time series is close to normal.

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[3] For a formal description see Harvey (1989).

Table 1: Descriptive statistics in Eur/Mwh

	NBP	Zeebrugge	Bunde
Mean	10.58	10.92	10.59
Median	10.05	10.49	10.40
Maximum	21.61	20.22	17.00
Minimum	1.86	5.69	5.70
Standard Deviation	3.11	2.48	2.16
Skewness	0.33	0.37	0.21
Kurtosis	2.64	2.74	2.62

4.2 ESTIMATION AND RESULTS

We use the Marquardt optimization algorithm for estimation of equation (5). All estimated coefficients are highly significant (results available upon request). Table 2 summarizes the main results of our time-variant analysis. When passing our data through the Kalman filter we assume the "stronger" trading place acting as exogenous variable, e.g. Zeebrugge being dependent on prices of NBP. Note that for the pair NBP – Zeebrugge only estimates of the first time-varying coefficient are reported.

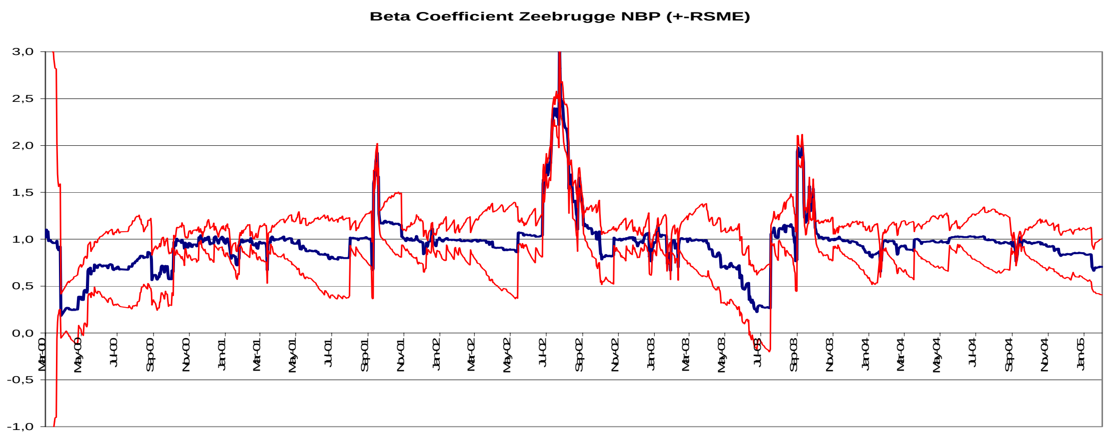
Table 2: Summary statistics of estimated beta-coefficients

	Beta Zeebrugge - NBP	Beta Bunde - Zeebrugge
Mean	0.9556	0.2397
Median	0.9709	0.2619
Maximum	3.0944	0.7027
Minimum	0.1809	-0.2588
Standard Deviation	0.3003	0.1691
Skewness	1.8661	-0.6088
Kurtosis	12.0989	3.9421
Final State	0.7054	0.4307
Root MSE	0.1614	0.0495
Observations	1645	705

Focusing on median values of estimated time-varying coefficients indicate a rather strong arbitrage relationship of prices at each end of the Interconnector. The relation of continental spot prices, on the contrary, remains rather weak. At the end of the time period investigated (beginning February 2005) traders active at the NBP or at Zeebrugge seemed to have the possibility to realize arbitrage profits.

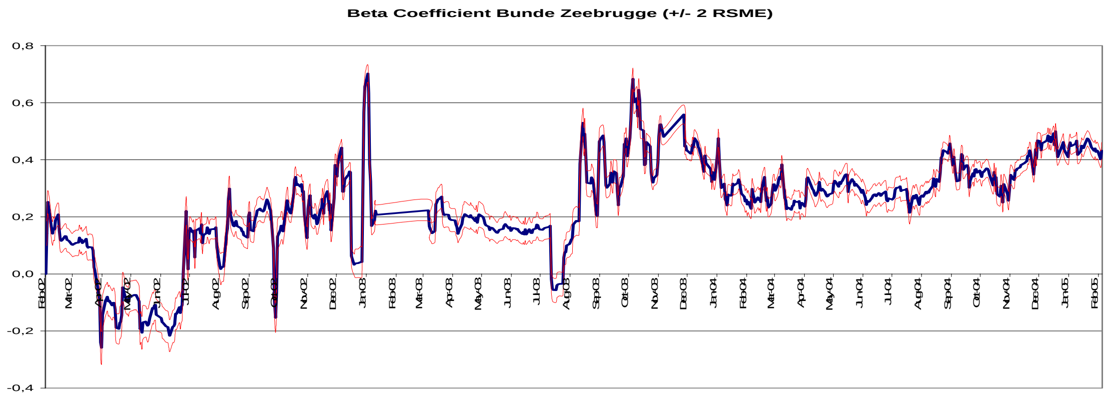
Figure 2 shows the estimates of the β_t-coefficient for the pair NBP and Zeebrugge. There is a clear trend of β_t towards 1 indicating price convergence via the Interconnector. The relationship between British and continental European prices has passed several stages. The first stage of strong convergence, including the first occasion of switching to reverse flows in January 2001, lasts until the planned shutdown of the Interconnector for yearly maintenance (September 2001) when prices diverge to only shortly afterwards converge again. Just when convergence was reached, the Interconnector again was closed due to serious liquid contamination (July 2002) and afterwards for yearly maintenance (August/September 2002).

Figure 2: Estimates of β-coefficient for the pair NBP and Zeebrugge



On the other hand, between Zeebrugge and Bunde we observe neither convergence nor a particular pattern of development of the β_t-coefficient. Results of the relationship Bunde – Zeebrugge are plotted in Figure 3. They indicate the absence of any relation between the two prices, although they are connected through a dense pipeline system. Obviously, the integration of the continental markets leaves much to be desired. This may be due to transport capacity constraints and/or the inefficient use of that capacity. A lack of liquidity at the Bunde trading point may also be responsible for the absence of price convergence between the two locations. In any case, the absence of integration of continental prices confirms allegations that the European natural gas market is not functioning properly.

Figure 3: Estimates of β-coefficient for the pair Zeebrugge and Bunde



5. CONCLUSIONS

In this paper, we have applied the time-varying Kalman filter analysis to test whether the prices of natural gas in the major European trading spots are converging. We find ideal type evidence of full convergence between the UK and Belgium, where the construction of a pipeline, the Interconnector, has made the law of one price to hold. Price convergence has taken place with the law of one price being confirmed for time periods when the interconnector has been utilized. Divergence of prices took place in periods during which the interconnector was either shut down or transporting at almost full capacity in only one direction.

On the contrary, we find clear evidence that the single European natural gas market is not working on the Continent. Prices at Zeebrugge and Bunde are not converging, even though these two locations are also connected by pipeline. Reasons for this may be an illiquid market at Bunde, inefficient use of transmission capacity, or strategic withholding of capacity by the monopolistic transmission operators on either side of the border. It seems that more stringent network access regulation is required to assure the proper functioning of the EU internal natural gas market.

The methodology can easily be extended to trivariate or multivariate analysis, once more data on the prices at other trading locations becomes available. The state-space formation of the dynamic model has proven to be a powerful tool of price analysis, pointing clearly at successes and failures of European integration policies.

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