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Linking Natural Gas Markets – Is LNG Doing Its Job?

Anne Neumann[1]

Abstract

The increase in liquefied natural gas trade has accelerated the integration of previously segmented markets in North America, Europe, and Asia. This paper provides evidence on the integration of the transatlantic natural gas market. We test the theoretical proposition that in integrating markets commodity prices should move closer than before. Using 2,059 pairs of daily spot prices for natural gas in North America and Europe we investigate price dynamics covering the period from 1999 until 2008. We apply the Kalman Filter technique to gain detailed information on trends inherent over time. Results suggest an increasing convergence of spot prices on either side of the Atlantic Basin.

Keywords: market integration, spot markets, LNG, natural gas

JEL-Codes: L95, Q49, F15

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1 Introduction

Markets for natural gas have witnessed profound changes in the past decade. Liberalization in most parts of the world, restructuring of former vertically integrated supply chains, and falling transportation costs especially for liquefied natural gas (LNG) have pushed the emergence of a new "international gas market", replacing the former regionally segmented markets in North America, Europe, and Asia. In addition, traditional pricing schemes are being reviewed moving from long-term, often oil-price indexed natural gas prices towards prices based on market mechanisms.

The literature on market integration in commodity and natural gas market has studied a variety of regional integration processes, but global natural gas markets per se have not yet been analyzed. The integration of the North American market following FERC Order 436 (1985) has been studied extensively, e.g. by Serletis (1997), Walls (1994), and De Vany and Walls (1995), who use correlation and cointegration analysis. Results of an integrated market were confirmed by studies using other econometric tools such as time-varying coefficients, Johansen test procedure, and impulse response functions, e.g. King and Cuc (1996), Cuddington and Wang (2006), and Serletis and Rangle-Ruiz (2004). Work on the cointegration of European natural gas import prices was first carried out by Asche, Osmundsen and Tveteras (2001, 2002). For the UK market, that has been liberalized 15 years earlier than Continental Europe, Panagiotidis and Rutledge (2007) show that the linkage between the natural gas price and the price of oil has become more volatile over time which can be interpreted as a sign of decoupling of the natural gas price from the oil price. Neumann et al. (2006) have shown that integration between the UK market and the largest Continental European wholesale market (Zeebrugge) works well, but that price convergence between different Continental European markets is still to come about. Last but not least, Siliverstovs et al. (2005) were the first to address the issue of international market integration for natural gas; they concluded that for the period preceeding liberalization of natural gas markets in Europe, i.e. the 1990s, the hypothesis of integrated transatlantic natural gas prices should be rejected.

The most recently finished EMF 23 study has a focus on prices and trade patterns in international natural gas markets presenting regional prices for natural gas. These are mainly calibrated by linking natural gas to petroleum prices (EMF, 2007, p. 18). However, price dynamics in natural gas markets may differ from those of crude oil, e.g. due to a different industrial organization of the sector. Existing literature analyzes the relation of different commodities (Hartley et al., 2008, Brown and Yücel, 2008, Villar and Joutz, 2006) and argues in favor of a long-run stable relationship of crude oil and natural gas prices. This paper provides evidence on the integration of international natural gas markets, hence spot prices for a single commodity. We test the theoretical proposition that in integrating markets of homogenous products, prices should move in the same direction; when achieving full integration, price differentials should only represent differences in transportation costs and/or quality. Construction of LNG import and export facilities worldwide facilitates flexibility in global trade of natural gas. Our hypothesis, spurred by evidence and market participants, is that as markets, in particular transatlantic natural gas markets, are getting closer intertwined, price integration is the natural consequence.

The remainder of the paper is structured in the following way: the next section describes the recent developments on the international gas markets upon which our hypothesis of increasing integration is based. Section 3 provides the model specification and explains the data on natural gas and oil prices. Section 4 presents the estimation results: we find a trend towards a higher level of integration between North American and European natural gas prices. Section 5 concludes.

2 Recent Trends in International Natural Gas Markets

International natural gas markets have gone through substantial institutional and economic changes during the past decade. This section describes the major changes on the North American and the European wholesale markets, and points out the critical role of liquefied natural gas (LNG) for the process of integration.

2.1 Development of trading hubs in North America and in Europe

North America pioneered the restructuring of natural gas markets as early as the 1970s, with deregulation of wellhead prices (Natural Gas Policy Act, 1978) followed by opening up of access to the trunk line natural gas infrastructure (FERC Order 436, 1985). Subsequently, the trading place "Henry Hub" in Louisiana emerged as the market centre. It is closely connected to not less than 16 pipelines, LNG infrastructure and three salt caverns for storage. Since 1988 Henry Hub serves as delivery and reference point for the New York Mercantile Exchange (NYMEX) gas futures contract and is the reference point for all natural gas export contracts to Mexico. Natural gas futures at the NYMEX have a depth of 5 to 6 years and are complemented by options since 1992. It is a liquid market serving as reference for almost all natural gas trade in North America.

The UK followed the US path with a time lag of about a decade. Breaking up the monopoly of British Gas in the UK in 1986 marked the landfall of the first truly competitive gas market in Europe. Already in 1994 the National Balancing Point (NBP), a notional trading point on the National Transport System (NTS), was used as an informal market and developed towards the main place for spot natural gas trading activities from 1996 onwards. There has been a steady increase in volume traded both physically and financially. A further expansion is expected once the LNG import quantities rise to substantial levels after the opening of import terminals (Isle of Grain, Milford Heaven). Recently, the NBP has served as a reference point for prices in long-term contracts, which has furthermore strengthened its role.

Continental Europe trailed far behind the US and the UK for a long time, until the EU Acceleration Directive (2003/55/EC) paved the way to a more stringent market opening. With regard to wholesale markets, the only significant development to date was the opening of the Zeebrugge hub (Belgium), after the connection with the UK through the Interconnector pipeline. Since its start in 1999, traded volumes have increased steadily. A second hub on the Dutch transmission grid (TTF) was set up in 2003 and has gained more importance since 2005. We seem to observe a certain "déjà vu" effect of repeated history of natural gas trading in Continental Europe, now in its early stages as was Henry Hub 20 years ago.

The restructured industry in Europe and North America features a high proportion of spot trading. Recent natural gas sales contracts are of a relative short duration comparatively to the traditional long-term contract. Contract prices are being keyed to a natural gas market indicator, since oil-linked pricing is a poor indicator of a gas-to-gas competitive market. Trade press reporting for a reference point such as the Henry Hub in America, the NBP in the UK, or Zeebrugge in Continental Europe provides transparent information about the market. This favors competition, an aspect to which we now turn.

2.2 Increasing role of LNG and emerging transatlantic competition

Given its ease of use and environmental friendliness, natural gas has become a key fossil fuel for the power sector and other industrial and residential demand. Demand for natural gas is increasing in all regions of the world, thus leading to upward pressure on prices and potential competition between the formerly segmented regions. In this context, the increase in LNG-trade provides the missing link for market integration across regions, in particular across the Atlantic Ocean. Although LNG has been around for about four decades now, it is only during the last decade that it has come to play a role as a serious means of interconnecting markets. In fact, one already observes an active arbitrage in the Atlantic Basin, where LNG shipments from Trinidad and Nigeria have been diverted either to the US or Europe depending on spot prices. The impact of these swaps and diverting activities has so far only been modest on the spot price in countries where cargoes have been sent to.

The three major natural gas consuming regions of the world (North America, Europe, and Asia) differ in their import structure. Whereas LNG so far has only played a minor role in North America representing 3.6 % of US natural gas consumption in 2007, countries like Japan and South Korea are fully dependent on LNG imports. In Europe both pipeline and LNG imports coexist and quantities differ on national levels. However, construction of a number of LNG importing facilities in the US and Europe should lead to significant interaction of these two regions.

According to theory, arbitraging possibilities occur in cases when the price differential of a homogeneous commodity exceeds transportation costs. Thus, convergence of North American and European prices should take place until the difference reflects only transportation costs. The technical prerequisites for LNG to play that role are fulfilled: there is an increasing amount of liquefaction and regasification capacities on either side of the Atlantic. Ship capacities are not critical, first, because there is a large amount of non-dedicated capacities under construction (IEA, 2007, p. 52), and second, there are no observable barriers to entry into that market. A favorable regulatory regime is established following the Hackberry Decision in the US and Article 22 of the European Gas Directive 2003/55/EC.

Recent evidence confirms the growing role of LNG: its share in global natural gas trade has risen to about 20% and is expected to reach 30% in the coming years (Cornot-Gandolphe, 2005). A growing share of this LNG-trade is short-term trading, about 11% (~20 bcm) in 2004, and rising (IEA, 2006).

Spot trading of LNG has so far mainly occurred during cold winter month, providing an opportunity to meet peak demand, and during times of substantial price differences between North America and Europe.[2] This is possible in times of increased flexibility inherent in long-term contracts. Natural gas storage deposits could be filled whilst sustainable low prices prevail, thus incurring strategic redirections of tankers to alternative market places performing at higher prices.

3 Data and Model Specification

3.1 Data

We are interested in the relation between natural gas spot prices on either side of the Atlantic Basin. Using daily data covering the time period January 1999 until May 2008 provides a sample with 2,059 pairs of observations when prices are reported for the same day in the transatlantic basin.

The National Balancing Point (NBP) and Zeebrugge refer to the European and Henry Hub (HH) to the North American price included in this analysis.[3] Quotations for the NBP and Zeebrugge are provided by Heren and converted from pence per therm into $/MBtu using daily exchange rates taken from the Federal Reserve Bank. Data on Henry Hub are as reported by the Energy Information Administration. Table 1 provides summary statistics of prices in levels and log-levels. Annual volatility, calculated as the standard deviation of the logged prices, was highest in 2005 when it reached 4.12 at NBP and 2.66 at the Henry Hub.

Table 1: Summary statistics

	NBP	(log)	Zeebrugge	(log)	Henry Hub	(log)
Mean	4.57	1.32	4.84	1.41	5.44	1.59
Maximum	33.75	3.52	33.59	3.51	18.85	2.94
Minimum	1.03	0.03	1.92	0.25	1.59	0.46
Std. Dev.	3.23	0.61	3.16	0.57	2.46	0.48
Skewness	2.27	0.32	2.29	0.34	0.79	-0.35
Kurtosis	11.65	2.62	11.88	2.91	4.20	2.37
Observations	2389		2223		2309	

[2] LNG imports to the US have decreased continuously since 2004 as flows were shifted from the US to markets in Asia and Europe (EIA, 2008).

[3] We include Zeebrugge prices since it is a trading place where LNG import facilities, long distance pipelines, and storage facilities intersect. Hence, a trading party would refer to Zeebrugge rather than NBP for possible LNG trade. However, spot cargoes have been mainly sent to facilities in Spain, but there are no price quotes publicly available for the time period under consideration.

3.2 Model Specification

Recent developments in LNG trade and expectations of developments are going to change the pattern of integration between natural gas prices in North America and Europe. These trends are unlikely to be caught in a framework of cointegration based on long-run relationships. Moreover, before markets or prices can be considered integrated they have to undergo a gradual change from separation towards integration. This is taken into account by introducing a time-variant coefficient into the linear relationship of prices. Considering prices for Henry Hub and NBP (Henry Hub and Zeebrugge, respectively) we constitute a linear relationship between these two:

$$P_{i,t} = c_{ij} + \beta_t P_{j,t} + \varepsilon_t \tag{1}$$

$$\beta_t = \beta_{t-1} + \mu_t \tag{2}$$

where P is the price in regions i and j, t denotes time and c_{ij} allows for transportation costs which are assumed to remain constant over time. Equation (2) determines values of β_t based on data of previous observations. If no profitable arbitraging opportunities arise prices are expected to equalize up to the difference in transportation costs, hence are considered to follow the law of one price. It holds for values of β_t equal to one, therefore prices are said to be more integrated the closer β_t is to one. This is valid since the price differential should converge towards transportation costs implying β_t to converge to the value of one. Formally, this can be expressed as $E\{\lim_{t\to\infty}(P_j - P_i)\} = c_{ij}$ with the final state of convergence represented by $E\{\lim_{t\to\infty}\beta_{ij}\} = 1$.[4]

We use the Kalman Filter technique to the whole sample of daily prices in order to gain detailed information on trends inherent over time. The Kalman filter processes the spot prices and provides information on the value of the parameters c_{ij} and β_t for each point in time over which both price series are available by proceeding in two successive steps. First, it estimates β_t by using information up to *t-1*. Following, information at time t is realized and the estimates of β_t are updated by incorporating prediction errors from the first step.

Hence, the filter produces linear minimum mean square error estimates of β_t using observed data up through time t. These estimates are optimally updated as data beyond t becomes available. The filter also ensures that the revisions made in β_t at time $t+k$ follow a (time-varying) moving average process of order $k-1$. If the error terms are assumed to be normally distributed, the parameters can be estimated by using the maximum likelihood method.[5]

An often voiced argument in context of this type of analysis of natural gas prices is the influence of oil prices. Even if it is argued that oil remains the driving force for natural gas prices we believe that prices for natural gas will behave increasingly independently of oil prices. Following the findings in

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[4] Hall, Robertson, and Wickens (1992) provide a refined interpretation of strong and weak convergence based on these expected values.

[5] See Harvey (1987) and Meinhold and Singpurwalla (1993) for a more detailed and technical description of the Kalman filter.

Hartley et al. (2008) we use prices at Rotterdam (ARA) for Europe and in Los Angeles, CA for US, (FOB quotes) to analyze this relation. Therefore we extend the analysis by applying the same technique to natural gas price data adjusted for the price of residual fuel oil. Hence, we generate two time series which are by definition uncorrelated to the price of oil but highly correlated with the price of natural gas.

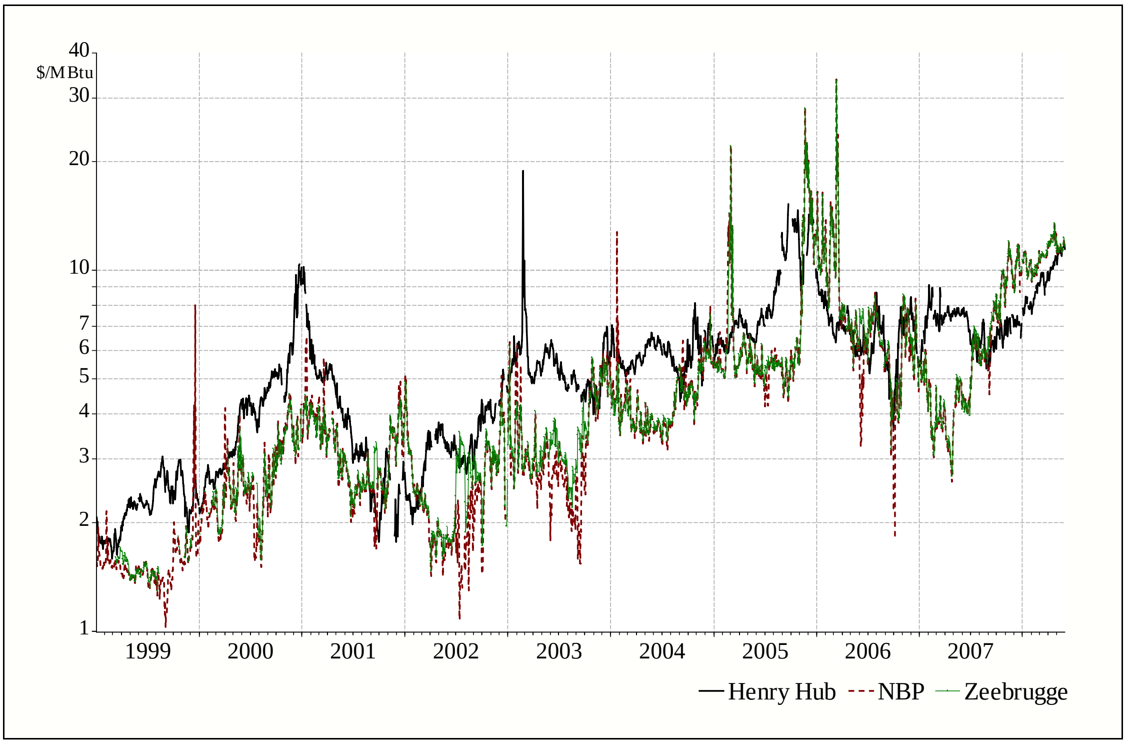
$$P_{i,t}^{NG} = c + P_{i,t}^{Oil} + \varepsilon_{i,t} \qquad i = \{Europe, USA\} \tag{3}$$

$$\tilde{P}_{i,t}^{NG} = \frac{\varepsilon_{i,t}\sigma^2{}_{P_i^{NG}}}{\sigma^2{}_{\varepsilon i}} + \overline{P}_i^{NG} \tag{4}$$

Following equations (3) and (4) results in new series for the Europe and the US which are the residuals of an OLS of the residual fuel oil price on the original natural gas price. Data is taken from EIA and converted from cent per gallon using a calorific value of 38,157 kwh. Equation (4) generates the final decorrelated time series ($\tilde{P}_{it}^{NG}$) by normalizing the variance of the residual series to the original series variance and adding the mean of the original price ($\overline{P}_{it}^{NG}$) to the generated data.

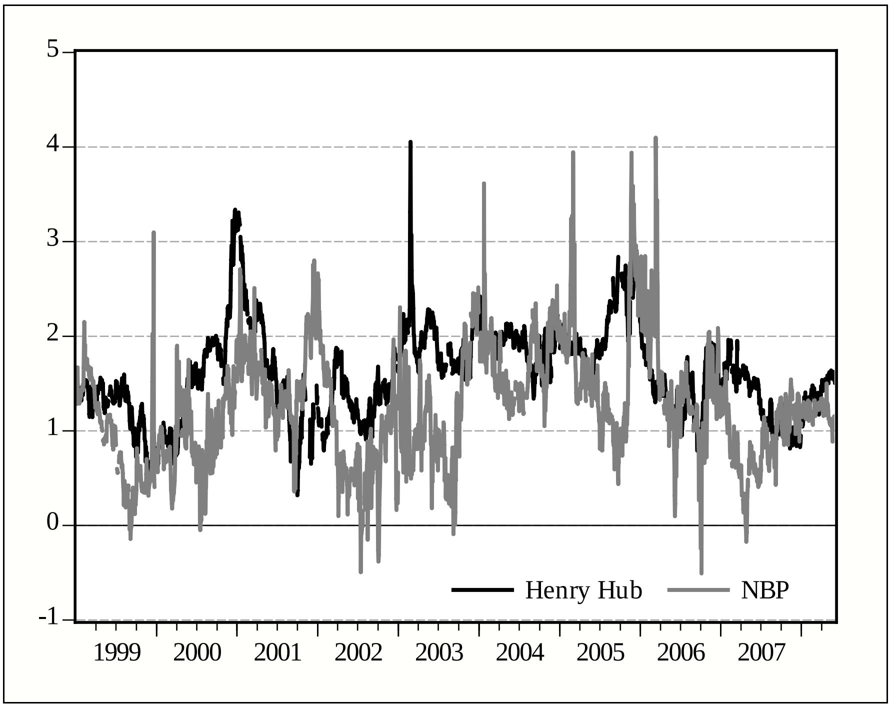
Figure 1 shows the original time series in levels using logarithmic scaling on the y-axis. The upward trend in prices for natural gas since the end of the 1990's is clearly depicted. Prices in North America and Europe are an image of one another until the end of 2002 with Henry Hub consistently prevailing at a higher level. Price spikes reflect exogenous influences such as the events around 09/11, hurricanes Rita and Katrina. Note that prices in the UK jumped to exorbitant levels in the cold winter 2005/2006 but have decreased to a conventional level since; the cold snap in January 2001 is clearly reproduced in Henry Hub prices. Zeebrugge prices mirror NBP prices, confirming the cointegration relationship shown in Neumann et al. (2006).

Figure 1: Natural gas prices



The generated decorrelated time series for natural gas in Figure 2 exhibit no clear sign of seasonality of prices for natural gas in the US where demand is driven by use in power generation during winter and summer alike. However, the pattern of the generated European price mirrors high demand for natural gas mainly during cold winter months.

Figure 2: Generated decorrelated gas prices



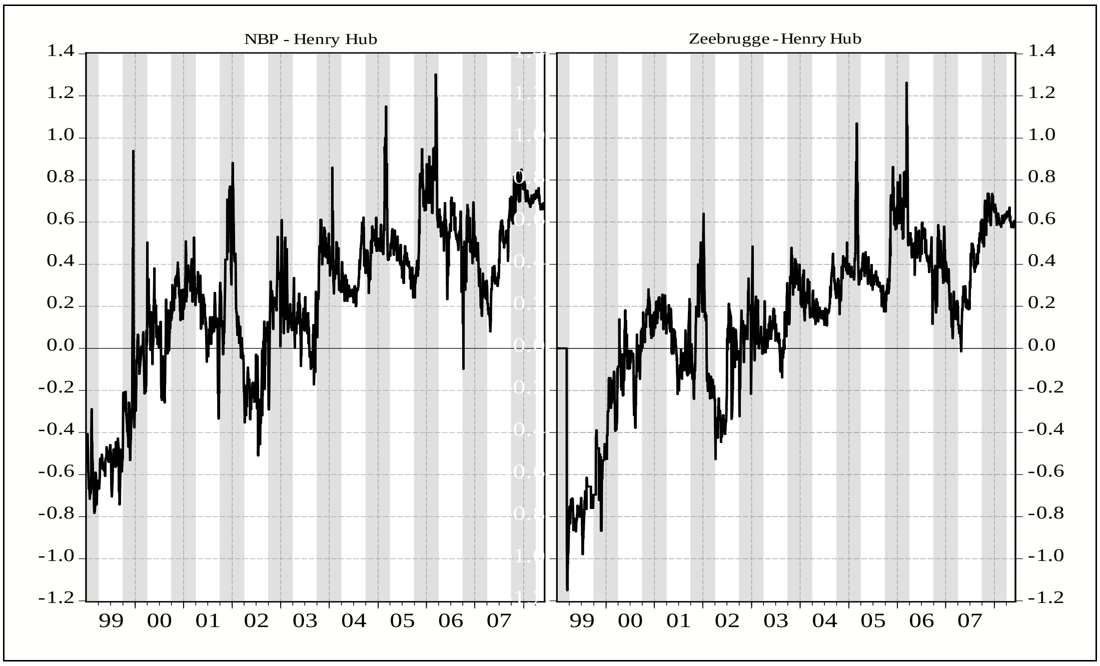
4 Results

4.1 Natural gas spot prices

The analysis investigates the relation between the natural gas prices on either side of the Atlantic, i.e. the Henry Hub and NBP / Zeebrugge spot prices over time from 1999 to 2008. Applying a time-variant coefficient methodology allows us to determine whether recent trends in international LNG trade have led to a convergence of spot prices in the US and Europe towards the law of one price. An application of the Kalman filter to daily pairs of logged spot data results in the estimation of the β_t-coefficient for the time period under consideration. Theory predicts that in a perfectly integrated market beta should be equal to one and c_{ij} would be interpreted to implicit transportation or transaction costs. Due to the non-normalized distribution of the estimated β_t, it is ambitious to test the statistical significance of this β_t -coefficient. Plotting the values of the coefficient over time provides an opportunity to evaluate whether or not convergence occurred. Figure 3 depicts in the left panel the result for the original natural gas spot prices assuming NBP to depend on prices quoted at the Henry Hub; the right panel shows the beta-coefficient for Zeebrugge and Henry Hub.

There is evidence of prices converging towards the law of one price for both estimated relations, hence the β-coefficient moving towards the value of one.[6] Interestingly, one could argue that there is some seasonality in the convergence more intensively occurring during winters (shaded areas) when markets are tight.

Figure 3: Beta coefficients



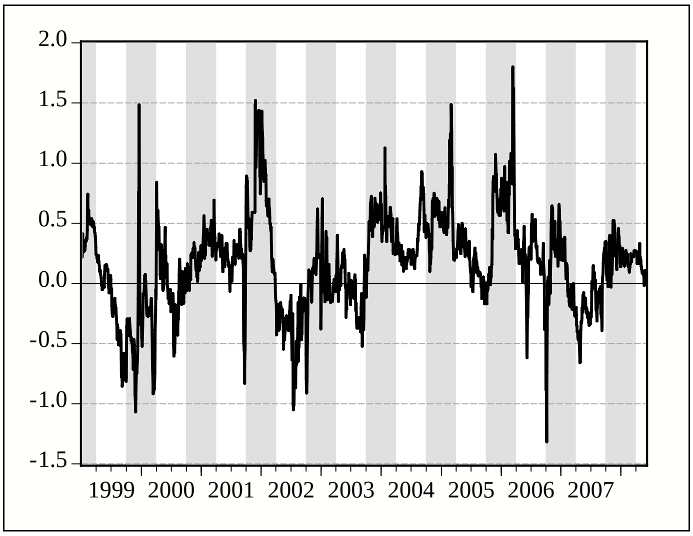
[6] For values of β_t not equal to one the interpretation of the variable accounting for transportation costs is rather ambiguous since there is no strict interpretation of this value in money terms. The filter does require a value of the mean and variance of β_0 to begin the recursions. These values are estimated prior to the adjustment process by using the maximum likelihood method (Harvey, 1987). Hence, the estimated β-coefficients at sample start are somewhat “distorted”.

4.2 Decorrelated prices

Accounting for the strong relationship of prices for residual fuel oil, mainly in power generation, we generated two time series highly correlated to the values of the respective spot price for natural gas in the US and Europe, but independent of oil prices. Applying the methodology of the Kalman filter as described above results in the beta coefficient as depicted in Figure 4.

Whereas there is no clear evidence of convergence towards the law of one price when adjusting for the influence of residual fuel oil, the graph of the estimated coefficients exhibits interesting features. First, for the period until approximately 2003, prices seemingly do not interact. However, some indications of beginning intertwining of transatlantic developments are suggested for the second half of the sample. In particular, we observe a stronger tendency of natural gas prices to converge during the winter season of demand (shaded areas). Also, it coincides with first spot cargoes delivered to Spain in Europe and signed swap deals.[7] Deliveries to the UK's terminal at Isle of Grain have followed the price difference of North American and UK spot prices since late 2005 (IEA, 2006). Rather surprising is the enormous impact of high prices in the UK during winter 2005/06 on the price relationship.[8]

Figure 4: Beta coefficients for NBP - Henry Hub (decorelated series)



5 Conclusion

This paper provides evidence on the integration of international natural gas markets. We have outlined the importance of LNG in the Atlantic Basin and reflected recent progress in the evolution of shorter-term trading for natural gas. LNG has been identified as the key driver for the transmission of regional impacts on prices. Hence, the market for natural gas is currently undergoing substantial change where regionally isolated markets are becoming more integrated. Under such circumstances, economic

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[7] Nigeria signed a deal with GdF and Enel in November 2005, GdF and Gazprom signed an arrangement allowing Gazprom to deliver a LNG cargo to Cove Point in the US.

[8] The Kalman filter has been applied to the two subsamples as described before with results almost identical to the one presented in Figure 3.

theory predicts that prices in two regions will converge towards the law of one price until the difference represents transportation or transaction costs only. Using daily data for the Henry Hub in the U.S., NBP in the UK, and Zeebrugge in Continental Europe, we apply a time-variant coefficient estimation methodology to test the hypothesis of price convergence covering the period from January 1999 until May 2008.

In a first step we apply the Kalman filter technique to the logged values of spot prices for Henry Hub and NBP. The results show evidence of prices converging towards the law of one price. Following, we adjust the original price series for the influence of residual fuel oil prices and natural gas generating two time series which are highly correlated to the price of natural gas but independent of oil. Results obtained from the Kalman filter methodology for the generated series are less evident of a convergence process, but provide some support for recent trends in transatlantic LNG trade. In general, we observe closer linkage between prices in the winter months, which seems a reasonable result.

Further research might extend this analysis to Asian markets. Another open question is what effect the recent price increase in oil and natural gas prices has on the market, and how LNG trading will develop under these circumstances. Last but not least, further restructuring of the natural gas sector in Europe and Asia should tend towards more liquid natural gas markets in these regions and, thus, favor the convergence of prices over time.

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