INTEGRATION OF ENERGY MARKETS: the case of USA-EU interdependence

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Abstract: In the vocabulary of international finance, markets are completely integrated if assets, having the same level of risk, have the same level of expected returns[2]. The current research aims to quantify the integration across markets in the energy sector. In particular we measure the degree of integration between the gas markets of the USA and the EU (represented by UK and Germany), by using commodity data on a nearest-future basis. We employ two classical approaches - rolling sample correlation and cointegration analysis, as well as a novel one - wavelet coherence, so as to uncover relationships in the frequency domain over time. Graphing the phase difference allows us to determine the market leader and the market follower. Our investigation broadly seeks to answer the question whether we can talk about a single global gas market, or the US and UK's and Germany's gas markets are more or less local; and whether global economic events such as the Global Financial Crisis bring them closer.

Keywords: energy markets; correlation; cointegration; wavelet coherence

JEL: F30, F36, G15

1. INTRODUCTION

The issue of integration across energy markets has been extensively studied at regional level (Asche, Osmundsen & Tveterås, 2002), and moreover - across commodities (Bachmeier & Griffin, 2006), (Neumann, Siliverstovs & Hirschhausen, 2006), (Mjelde and Bessler, 2009) and (Westgaard et al.,2011)). Nevertheless, the problem of international energy market co-movements has become an important research problem during the last years (Siliverstovs et al., 2005), (Warell, 2006) (Papież & Śmiech, 2015). In particular, as a result of the interruptions of gas supplies in 2006 and 2009, the EU has prioritized the security of supplies and diversification and has set measures, aiming at the creation of an internal energy market[3]. The steps undertaken during the last 5 years towards a common EU energy policy and increased physical interconnection between the member states among others, are expected to gradually lead to an improved level of integration between markets.

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[2] An extensive discussion is available in (Bekaert, 1995).

[3] For this purpose the EU has set targets for 10% interconnection capacities by 2020 and set aside €1.4 billion worth of projects for the construction of missing gas links. According to EU 2013 statistics, gas import equals 66% of the total gas consumption - about 39% comes from Russia, 34% from Norway and 14% from Algeria.

The policies and measures, mentioned above, have been directed towards diversification of the channels of supplies. Setting aside the option of an increase in domestic production, where possible, increasing diversification can be also achieved by having a wider portfolio of sources of origin. In terms of gas supplies, the EU has recognized the importance of the liquefied natural gas (LNG), which offers flexibility as well as access to global gas markets. Similarly to conventional natural gas, LNG requires expensive infrastructure – namely, regasification terminals[4]. An increased regasification capacity is expected to positively affect the integration of the EU gas market with the global market, and in particular to that of the USA. The goal of the current paper is to provide an in-depth analysis of the integration between the US and the EU energy markets. We engage correlation, cointegration and wavelet analysis in order to reveal the dynamics in the existing dependencies. Furthermore, we determine the market leader and the market follower.

It is worth mentioning that choosing the US gas market for that purpose is not arbitrary. Thanks to the shale gas and oil boom, since 2006 the USA has gradually become a net energy exporter, already turning some LNG import terminals to export ones. Some economists believe that the shale revolution has brought down gas prices not only domestically, but shall shape the gas price internationally. Another major event that influenced the trends on a global scale is the Fukushima disaster in 2011. It caused the shutting down of nuclear plants in Japan and South Korea and in combination with a rise in gas consumption in China, has increased the demand for gas in Asia and diverted LNG tankers to the eastern direction.

In the light of the current research, one aspect of the EU and the German gas markets in particular is worth mentioning. They have been shunned from the global market trends due to the legacy of the long-term contracts with suppliers. Not only had those contracts spanned for several decades, but the majority of the gas supplied from Russian and the LNG from Qatar, had been oil- indexed. Since 2012 Dutch and Norwegian gas contracts, and in some cases Russian gas contracts, have been either fully or partially gas-to-gas indexed, based on hub spot-price. It is estimated that the share of hub indexations in Europe was between 30% and 55% in 2013[5] and close to 60% in 2014[6]. As a result, we expect an emerging trend towards integration of the UK and German gas markets with that of US. From this perspective, the current paper focuses on the integration of UK's and Germany's gas markets with that of the US.

Rest of the paper is structured as follows. Section 2 provides an overview on the methods for measurement of market co-movements. Section 3 describes the data set and presents our major results in the context of a discussion. Section 4 concludes.

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[4] However, the opportunity to source gas from producers introduces competition and prices that reflect the international trends. Such ports exist in several countries in the EU: Greece, Portugal, Spain, Italy, France, Belgium, the Netherlands and the United Kingdom.
[5] Long-Term Gas Import Contracts In Europe. 2014
[6] World Gas Intelligence, 25 June 2014

2. METHODOLGY

Typically, correlation, cointegration and wavelet coherency analysis are among the major research tools used for detection and measurement of the strength of integration between two markets. The interested reader might find an extensive discussion on the topic in (Богданова, 2014). In the text that follows we briefly present the essence for each of the utilized methods.

The major advantage of the correlation analysis is its simplicity of application. It involves calculation of a pairwise Pearson correlation coefficient ρ. Instead of estimating ρ over the entire data set of T observations, one might adopt a sliding window of length n. Thus a sequence of estimates $\{\hat{\rho}_i, i = 1, \dots, T-n\}$ is obtained, which provides information on the dynamics of the analyzed dependencies (see (Стоянов, 2011), for example). Alternatively, an estimation of the dynamic conditional correlations of Engle (Engle, 2002) might be performed, which, however, is a way more involved task. Therefore, in this paper we stick to the sliding window approach.

As highlighted by Click and Plummer (Click & Plummer, 2005), the correlation coefficient is calculated usually over data sampled at daily, weekly, or monthly frequency, which in turn allows to analyze the short term dependencies in the data, yet, it is hard to draw any conclusions on the presence of long term relationships. From this perspective many authors utilize cointegration tests when studying integration between a group of markets (see the paper of (Jochum, et al., 1999) and the references therein). Let's denote by $\{X_t, t = 1, \dots, T\}$ a vector of N elements, where each element corresponds to an individual time series. According to (Engle & Granger, 1987), the elements of X_t are co-integrated of order (d, b) if $X_t \sim I(d)$ and a vector α ($\alpha \neq 0$), called co-integrating vector, exists, such that $z_t = \alpha' X_t \sim I(d-b), b > 0$. In a sequence of papers ((Johansen, 1991), (Johansen, 1995), (Johansen, 1988)) Johansen develops a test procedure where the null hypothesis is presence of r ($r \leq N-1$) or less co-integrating vectors. At the core of the test is the following representation:

$$\Delta X_t = \Gamma_0 + \Gamma_1 \Delta X_{t-1} + \cdots + \Gamma_{k-1} \Delta X_{t-k+1} + \pi X_{t-1} + \varepsilon_t, \quad (1)$$

where $\pi = \beta\alpha'$. The π matrix in Eq. (1) is estimated for an unconstrained VAR model and then tests on its rang r are performed. One of the important advantages of the cointegration test is the fact that it enables analysis of the integration of more than two markets at the same time. We perform cointegration test of Johansen through the Matlab function jcitest.m.

Finally, we employ wavelet analysis, which involves calculation of a wavelet coherency matrix. The text that follows provides a brief description of this idea, while the reader might find an exhaustive discussion in (Aguiar-Conrara & Soares, 2014). A function $\psi(t) \in L^2(\mathbb{R})$ is said to be a mother wavelet if it satisfies the so called "admissibility condition", which comes down to $\Psi(0) = \int_{-\infty}^{\infty} \psi(t)dt = 0$ for functions with sufficient decay, where $L^2(\mathbb{R})$ denotes the set of square integrable functions and $\Psi(\omega)$ denotes the Fourier transform of $\psi(t)$. A family of wavelet daughters $\{\psi_{\tau,s};\ s, \tau \in \mathbb{R}, s \neq 0\}$: $\psi_{\tau,s} = \frac{1}{\sqrt{|s|}} \psi\left(\frac{t-\tau}{s}\right)$ can be obtained by scaling and translating the mother wavelet ψ, where s is a scaling factor controlling for the width of the wavelet and τ is a translation parameter controlling its location.

Given a time series $x(t)\epsilon L^2(\mathbb{R})$ its continuous wavelet transform with respect to the wavelet ψ is defined as follows:

$$W_{x;\psi}(\tau,s) = \int_{-\infty}^{\infty} x(t)\frac{1}{\sqrt{|s|}}\psi^*\left(\frac{t-\tau}{s}\right)dt, \quad (2)$$

where the asterisk denotes complex conjugate. For simplicity of notation the wavelet transform $W_{x;\psi}(\tau,s)$ will be denoted by W_x in the text that follows. The cross-wavelet transform of two time series, $x(t)$ and $y(t)$, is given by $W_{xy} = W_x W_y^*$. For the purpose of measuring co-movement it is suitable to utilize complex-valued wavelet. The most common choice is the Morlet wavelet which is utilized in the current paper as well. The wavelet coherency of the time series $x(t)$ and $y(t)$ is denoted by R_{xy} and is defined by Eq. (3):

$$R_{xy} = \frac{|S(W_{xy})|}{\left[S(|W_x|^2)S\left(|W_y|^2\right)\right]^{1/2}}, \quad (3)$$

where S is a smoothing operator in both time and scale and $0 \le R_{xy} \le 1$. The closer the value of R_{xy} to 1, the stronger is the degree of synchronization between the time series $x(t)$ and $y(t)$, i.e. they are exhibiting stronger co-movement. As might be seen the wavelet analysis provides time-frequency breakdown of the complicated dependencies contained in the data, which is a major advantage. Furthermore, it allows calculation of phase difference ϕ_{xy}, which allows to determine the leading and the following market. The series y is leading the series x when $\phi_{xy} \in \left(-\frac{\pi}{2},0\right)$ or when $\phi_{xy} \in \left(\frac{\pi}{2},\pi\right)$, in the first case the two series are moving in phase and in the second case there is an anti-phase movement.

The calculations of the wavelet coherency and the phase difference are performed through a freely available Matlab toolbox associated with the theoretical framework presented in (Aguirar-Conrara & Soares, 2014). The toolbox is available at http://sites.google.com/site/aguiarconraria/joanasoares-wavelets.

3. DATA and RESULTS

3.1. Data

The current research focuses on the co-movements of the UK and the German gas markets in relation to the US gas market, since it has evolved as major factor in the recent global market trends. In order to study the dependence between energy markets, historical prices of gas futures are employed. The series consist of closing prices of front month contracts[7]. The US market is represented by gas futures, traded on the New York Mercantile Exchange (NYMEX). Due to lack of a single energy exchange in the EU, data from the London-based Intercontinental Exchange (ICE) represent the UK gas market and gas futures traded on the Leipzig-based European Energy Exchange (EEX) represent the German gas market. All the price series are weekly and cover different time spans, summarized in Table 1. The reasons for choosing weekly periodicity is on one hand, to avoid

[7] Similarly to (Vacha & Barunik, 2012) we use continuous Contract #1. Additionally, the reason for choosing futures prices, and especially those bound by physical delivery, is to avoid the high volatility of the spot-markets.

the high volatility of daily prices, and on the other – to overcome the differences in working hours of the three exchanges during holidays.

Table 1: Start date and end date of the analyzed data sets.

	Start date	**End date**	**Number of observations**
Natural Gas Futures Contract 1, NYMEX (USA)	13-Jan-1994	16-Jun-2015	1 118
Natural Gas Futures Contract 1, ICE(UK)	2-Feb-1997	16-Jun-2015	959
German Base-load Electricity Futures Contract 1, EEX (DE)	5-Oct-2007	16-Jun-2015	402

Figure 1 provides a graphical representation of the three price series. It can be seen that the US and UK price series exhibit some similar patterns, also the German and the UK gas future prices move quite close. For the purpose of our research, the price series are transformed into logarithmic returns and their descriptive statistics are presented in Table 2.

Figure 1. Natural gas future series

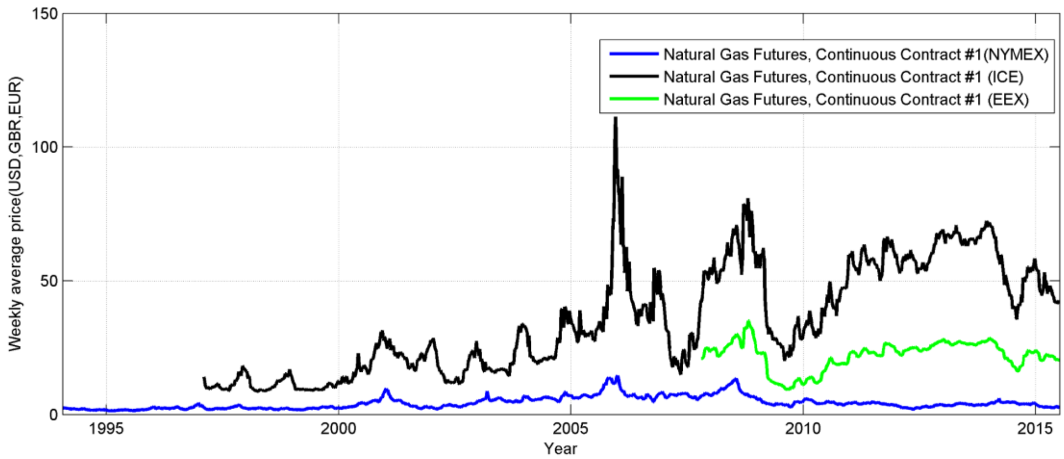


Table 2: Descriptive statistics of the analyzed gas futures logarithmic returns.

	Gas Futures , NYMEX (USA)	**Gas Futures , ICE(UK)**	**Gas Futures, EEX (DE)**
Mean	0.0002	0.0012	-0.0001
Standard deviation	0.0618	0.0782	0.0358
Skewness	0.1790	0.6858	-0.1899
Kurtoisis	4.9381	7.5994	17.0425
ADF test	-28.9998	-32.4272	-12.7969
JB test	180.7863	919.5122	3297.1000

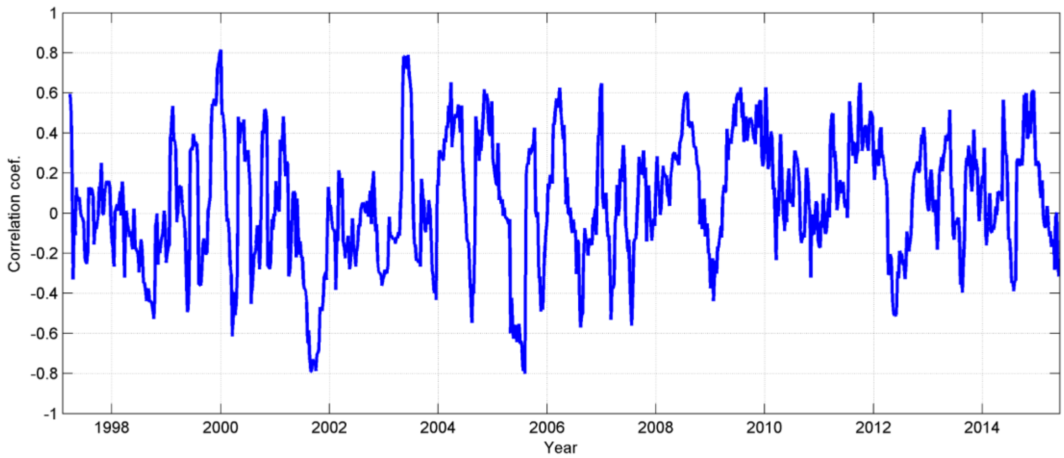
American and English gas futures have positive mean return, but they are characterized by higher volatility, and positive skewness. The German futures have a small but negative return and skewness and are less volatile than the other two series. Judging on the value of the kurtosis and result from ‘Jarque-Bera test’, all the return series have distributions statistically different from the normal distribution and considering the German gas returns, some outliers lie as far as 17 standard deviations from the mean. The

‘Augmented Dickey-Fuller’ rejects the null hypothesis for the presence of unit root in three series.

3.2. Results

Figure 2 shows the rolling correlation coefficient of gas future returns of UK and US over time. No long periods of a strictly positive or a strictly negative correlation are observed, but rather a cyclical pattern. The correlation coefficient for the whole observed period (1997 – 2015) is only 0.0802, but still positive, and a little higher (0.1723) for the period 2007-2015. Two extreme cases are observed – these are in middle of 2001 and middle of 2005. In both cases in the short to medium run the return series moved in completely opposite directions: the findings could be explained with two major events that originated in and affected the USA the most. The former period is marked by the terrorist attacks on 9/11, while the latter period falls into the aftermath of the Hurricane Katrina (Aug. 2005), which resulted in a decrease in oil and gas production in the USA for half a year.

Figure 2. Rolling sample correlation between the returns of the US and the UK gas futures returns

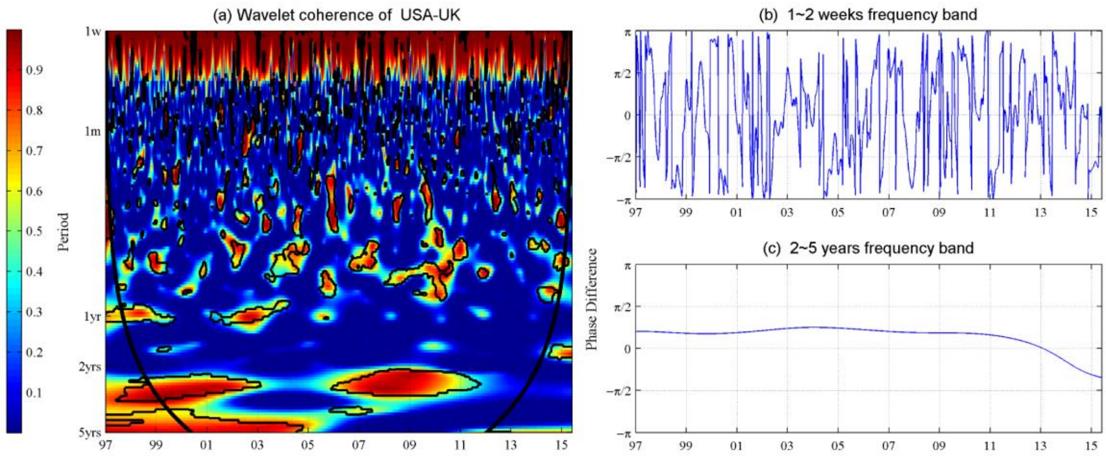


From a long-term perspective, according to the Johansen cointegration test results, summarized in Table 3, there is no cointegration between the two price series over the whole period (1997 – 2015). The same statement holds true about the sub-period 2011-2015 and the only exception is for the period 1997-2010.

Table 3. Summary results of the performed Johansen cointegration test (US – UK gas future series)

	p-value of Johansen cointegration test		
Cointegration rank (r)	1997-2015	1997-2010	2011-2015
0	0.0677	0.0037	0.1798
1	0.0181	0.0373	0.0419

Figure 3. Wavelet coherence between the US and the UK futures log-returns (a), phase difference corresponding to the 1 week – 2 weeks frequency band (b), phase difference corresponding to the 2 – 5 years frequency band (c)



Prior to discussing the results from the wavelet analysis presented at Figure 3, a brief comment on the color map displayed at panel (a) should be done. Each pixel of the map corresponds to a particular value of R_{xy} and the color code is provided next to the map. The x-axis represents the time line and the y-axis corresponds to the utilized frequencies, which are converted into time units in order to ease interpretation of results. The highest frequency is one week and the lowest frequency corresponds to five years. Statistically significant coherencies are determined on the basis of Monte Carlo experiments and then they are contoured on the map. The cone of influence represents the region in which the transform suffers from edge effects and it is plotted with tick black line. In this region the results should be interpreted with special care.

According to panel (a) of Figure 3 there is a significant co-movement between the UK and the US market only in the high frequency domain. This indicates that in the short run, these two markets react to news in a similar manner. A noteworthy, and significant co-movement can be observed in the lowest frequency domain too (2-5 years), as shown by the hot areas between the years 1999-2002 and 2006-2011. These findings are in compliance with the low correlation values throughout the period under study, as well as with the observed increase during the period of the 2007-2009 financial crisis. Furthermore, the color map provides information on the term structure of the existing dependencies. We additionally deepen these findings via inspection of the calculated phase difference. Judging by the chaotic high-frequency phase difference, visualized at panel (b) of Figure 3, neither series precedes the other. However, in the low-frequency range (panel (c)) the phase difference is between 0 and π/2, suggesting that the US series leads the UK one. These findings have important implications for analytical as well as for predictive purposes.

In passing, we should note that the color map explains the lack of cointegration in the post crisis period. The presence of cointegration implies the existence of long-term relationships therefore a close inspection of the low-frequency band co-movements is performed. As might be seen, after 2010 the color map is prevailed by statistically insignificant coherency values, which is in compliance with the results reported in Table 3. As for the periods before and during the crisis, the observed red regions suggest a strong co-movement between the two series, which however, is attributed not to their linkage, but rather to the presence of major global events, affecting both. As stated above, in the absence of such events (2010 – present), the regions are blue.

Figure 4. Rolling sample correlation between the returns of the US and the German gas futures returns

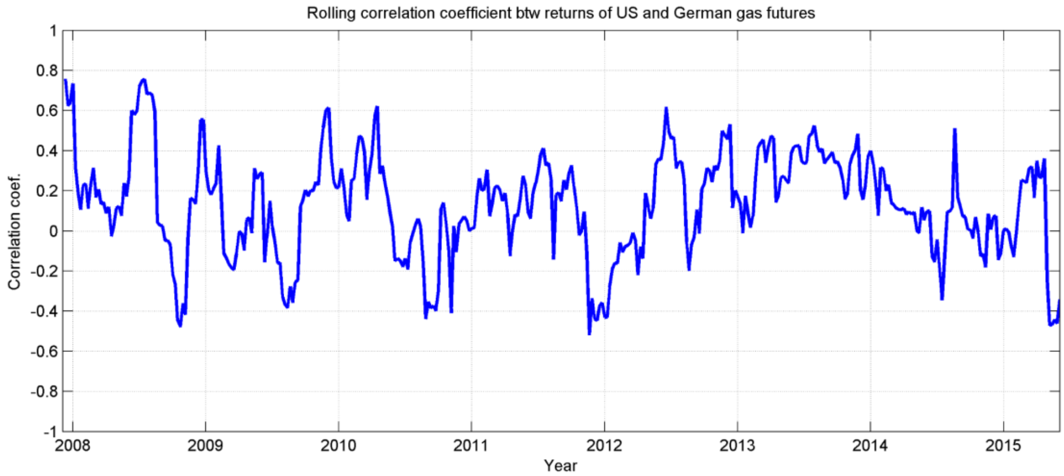


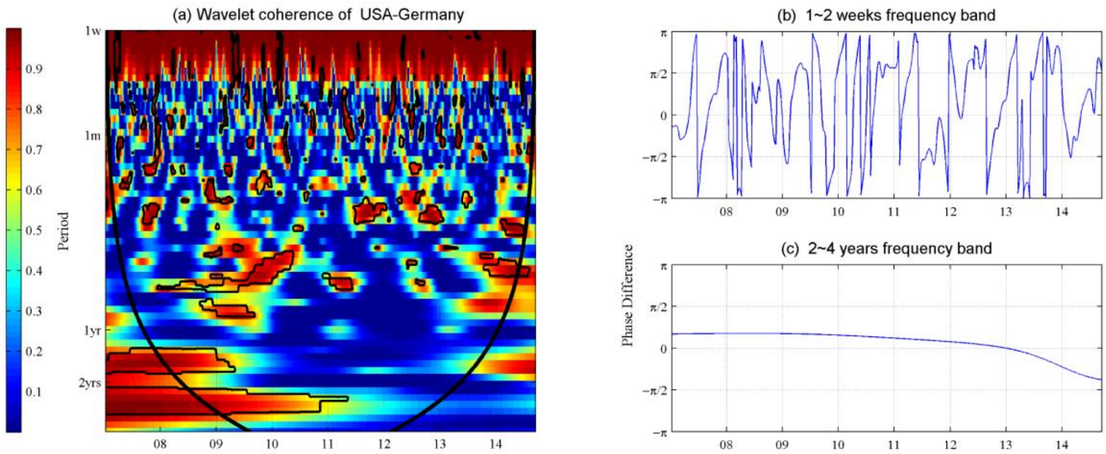
Table 4. Summary results of the performed Johansen cointegration test (US – German gas future series)

	p-value of Johansen cointegration test		
Cointegration rank (r)	1997-2015	1997-2010	2011-2015
0	0.6661	0.4118	0.1174
1	0.0968	0.1537	0.0217

Figure 4 shows the rolling correlation coefficient of gas future returns of US and Germany over the period 2008 - 2015. The correlation is positive, but weak over time, with an average correlation coefficient of 0.1337. What should be noted is that there are several occasions where the correlation is negative, for example: end of 2008 (the financial crisis) and March 2011 (the Fukushima disaster) What should also be noted is that the period between the middle of 2012 and the middle of 2014 is characterized by a weaker dependency – fluctuating around 0.4.

The results of the Johansen Cointegration test, reported in Table 4, are in compliance to the results of the wavelet coherency analysis. Panel (a) of Figure 5 displays a similar pattern to the one for US-UK over the frequency-time domain. Again, the co-movements are significant only for the highest frequencies. As for the low ones, the two series exhibit strongly pronounced dependencies until 2011. In the aftermath the area progressively becomes colder, signifying a structural break or the attenuation of the global financial crisis. We drew the same conclusion for the US-UK series. The high-frequency phase difference graph in panel (b) of Figure 5 shows no persistent pattern. In the low frequency domain, however, it is evident that the US market is the leading one, confirmed by the phase difference consistently between 0 and π/2. Moreover, until 2011 positive returns of the US futures are followed by positive returns for German ones, while after 2011 the coherence is insignificant, therefore this part of panel (c) should not be taken into account.

Figure 5. Wavelet coherence between the US and the German futures log-returns (a), phase difference corresponding to the 1 week – 2 weeks frequency band (b), phase difference corresponding to the 2 – 4 years frequency band (c)



The color map of Figure 5(a) reinforces the conclusion from the cointegration tests, listed in Table 3, that in the long run, after 2010 the two markets follow different paths. This can be attributed to the fact that after 2010 natural gas prices increase in Germany and globally, while decreasing in the USA, due to the high domestic production of shale gas. Furthermore, in the medium-frequency domain (1 month – 2 years), the coherence values are insignificant, supporting the low rolling sample correlation coefficients, observed in Figure 4.

4. CONCLUSION

The current paper utilizes three distinct statistical approaches to analyze the co-movement of the natural gas markets of USA and Europe (represented by UK and Germany) over different frequencies in the time domain. Rolling sample correlation was the method of choice for analyzing low and medium-term relationships, cointegration tests – for long-term relationships, and wavelet coherence – for covering the whole time-frequency domain. Our major findings are that: in the long run USA is the leader and is followed by the two European markets; for the studied period (2007-2015) in the short run the three markets react similarly, and simultaneously, to economic news; in the medium and long run the gas markets of USA and Europe are not integrated, but are bound together only in times of major global economic events. The conclusions from the rolling sample correlation and cointegration tests coincide with the ones from the wavelet coherence method, affirming the results' robustness.

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