Liquidity in the NBP Forward Market

Marianna Russo
Lilian M. de Menezes
Giovanni Urga
Cass Business School, City University London
London, United Kingdom

***Abstract*— Liquidity in the National Balancing Point (NBP) forward market during 2010-14 is examined using liquidity measures adopted from the financial literature. Since the sample period includes the date when the EU Regulation on Market Integrity and Transparency (REMIT) became in force, the question of whether changes in these measures reflect REMIT is also investigated. There is evidence of increased market transparency and competition, which are of interest to policy makers and regulators. No significant differences in the level of liquidity in the NBP one-month-ahead market appear to have followed the introduction of REMIT.**

***Index Terms*—Liquidity, natural gas, OTC markets, regulation, time-varying processes.**

I. INTRODUCTION

Following the liberalization and development of natural gas trading hubs in Europe, forward products have become a response to the increased exposure to price risk that energy companies face in the spot market. Financial institutions and non-physical traders were encouraged to participate in the European natural gas market, and have further contributed to the development of trading hubs. Yet, concerns over the impact of investors on market quality have been raised, mainly when trading occurs in the less transparent over-the-counter (OTC) markets [1][5].

To foster stability and transparency, the European Commission has introduced several regulatory proposals, among which is Regulation (EU) No. 1227/2011 on wholesale Energy Market Integrity and Transparency (REMIT), which has been in force since December 2011 and effective from 7 October 2015.

Wholesale markets encompass both commodity and derivatives, which are either physically or financially settled. REMIT introduces a monitoring framework to detect and prevent market abuse, particularly in the OTC market. Monitoring requires regular and timely access to records of transactions as well as data on capacity and use of facilities for production, storage, consumption or transmission of electricity or natural gas. Market participants, including transmission system operators, suppliers, traders, producers, brokers and large users who trade wholesale energy products are required to provide that information to the Agency for the Cooperation of Energy Regulators to ensure that prices are a fair and that no profits can be drawn from market abuse.

Although higher transparency can reduce transaction costs and lower barriers to market entry, which may improve liquidity [6][7], REMIT's effects on market quality and liquidity are unknown. For example, large commercial participants (e.g. energy companies) may be more knowledgeable about retail market developments and reluctant to post orders that would give away this informative advantage. This could lead to a deterioration of liquidity, e.g. [8], and higher market entry barriers for small commercial participants, thus compromising competitiveness, investment decisions and market efficiency. Moreover, the amount of reporting poses high administrative costs on market participants that may increase rather than reduce transaction costs, thus making the markets less attractive. Reduced trading activity from investors could decrease liquidity and lead to market instability. Hence, measuring liquidity is relevant to cost the hedging, undertake investment decisions, and to aid regulators and policy makers in monitoring market quality in the context of the evolving liberalized European energy markets.

The aim of the present study is to assess liquidity in the NBP forward market, which is the main pricing hub in Europe [9] [10] and can be regarded as representative of the European natural gas market. Several measures of liquidity borrowed from the financial literature, and inspired by microstructure theory, e.g.[11] are used. A time-varying setting is adopted, in order to investigate changes in liquidity that may have followed the introduction of REMIT.

The remainder of this article is organized as follows. In Section II, the liquidity measures in energy and financial markets are reviewed. Section III describes the data and methods. The empirical results are reported in Section IV. Finally, Section V discusses the main findings and their implications.

II. LITERATURE REVIEW

Liquidity is a measure of market quality, defined as the ability to match buyers and sellers at the lowest transaction cost [11]. This definition focuses on the trading mechanisms and the evolution of asset pricing in the markets. Higher transactions costs imply lower asset prices and higher rate of returns, required to compensate investors for bearing the liquidity cost. This aspect has been extensively investigated in the financial literature, e.g. [12]-[16], and denotes the ability of a market to offer sufficient opportunities for trading, such that individual trades have a limited impact on market prices. A lack of liquidity may impede trading, thereby making it easier for one market player to assume a dominant position, with implications for price fluctuations.

Practitioners in natural gas and power markets usually refer to the churn ratio as measure of liquidity, e.g. [17]. This measure is the ratio of the trading volumes to the physical deliveries after trades: the higher this ratio, the greater is the market liquidity. Although simple to calculate and useful when comparing markets, the churn ratio is driven by physical deliveries which, in natural gas markets, are seasonal and weather-dependent. Furthermore, it encompasses trading activity, which may be associated with higher volatility, thus implying lower liquidity [18][19]. A rigorous and empirically relevant measure of liquidity in energy economics remains a challenge, mainly due to the multiple dimensions involved. Liquidity comprises important transactional properties of a market such as tightness (the cost of turning around a position over a short period), depth (the size of an order flow innovation required to change price of a given amount), and resiliency (the speed with which prices recover from a random, uninformative shock) [20]. In common, these properties define liquidity as a cost. However, there is no consensus on which would be the best measure to capture this cost. In the financial literature, different measures of spread and price impact have been proposed to assess market liquidity, e.g. [14] [21].

Measures of spread

Spread is a proxy for tightness. Commonly used measures are the quoted bid-ask spread and the effective spread [22]-[26]. They originate from a microstructure model where costumers trade only with market-makers, with bid-ask midpoint (mid-quote) from the most recent best bid and ask centered, on average, on the fair asset value, [24] [26] [27]. The quoted bid-ask spread is defined as the difference between the most recent best ask and bid quotes. It represents the cost of a "round trip", which is a purchase followed by a sale for small quantities.

Stoll [28] observed that quoted bid-ask spreads may overstate transaction costs, because either traders are better informed than the market-makers, or market-makers adjust the bid-ask spread to control for their inventory. In this respect, the effective spread, which is defined as the difference between execution prices and mid-quotes, is an estimate of the actual transaction cost as it recognizes that trades may occur at prices other than the mid-quotes.

The realized spread is similarly defined, but refers to the actual spread which follows a trade. It represents the non-informational component of the effective spread, which should lead to a temporary deviation of the price from the underlying value, measured by the price reversal immediately after a trade, e.g. [24].

To date, measures of spread were used, among others, by [13] [14] [21] [30] [31] to evaluate liquidity in financial markets. They were also employed to assess liquidity in the U.S. commodity markets by [32]-[34], and in the Nordic power market by [35].

Measures of price impact

In a high-frequency setting, measures of price impact are used to evaluate two aspects of liquidity: depth and resiliency, e.g. [15] [36]. The price impact is defined as the temporary changes in execution prices following an order flow, where the order flow is set as the signed volume [15]. A measure of price impact is defined as "the price change associated with the aggregated signed square-root dollar-volume" over the same time interval [16]. [37]-[39] employed the expected return reversal to measure of price impact. The relationship between price changes and order flow, defined as difference between the numbers of buy and sell initiated trades, was adopted as proxy for price impact by e.g. [40]. In all, there is no consensus on how to assess liquidity, and different measures are explored in this study.

III. DATA AND CONSTRUCTION OF LIQUIDITY MEASURES

The dataset

This study uses a unique dataset consisting of tick-by-tick indicative quotes (best ask and best ask), execution prices and volumes from the inter-deal broker Tullett Prebon (http://www.tpinformation.com). One month-ahead forward NBP data for the period May 2010-December 2014 (461,663 records) are available and represent about a third of the total trades in the sample period. Hence, liquidity dynamics are investigated in a particular trading venue. Notwithstanding, the share of the market is not small, and the analysis that follows should be informative with respect to the NBP forward market.

As in previous literature, [41] [42], observations outside the interval 7:00-17:00, weekends, holidays, entries with negative spreads and outliers are removed. Simultaneous records at each time t are aggregated according to their medians (quotes and execution prices) and totals (volumes and number of trades). Approximately 2% of the sample is discarded, thus resulting in 78,019 records, which are then resampled at 60-minute-frequency, as in [43] [44], to reduce effects of microstructure noise in high-frequency irregularly spaced series [45]. The first return of each day is discarded, as it might reflect adjustments to the overnight information. The final sample has 12,870 observations. Given the expected effect of the yearly seasonality of the demand for natural gas on quotes and execution prices and volumes, adjustment regressions are performed on the raw series to account for a trend and seasonality [46].

Assessing liquidity in the NBP forward market

The first measures adopted relate to the spread: the effective half-spread (EHS) and the realized half-spread (RHS), i.e.

$$EHS_{\tau} = D_{\tau}\left(\frac{P_{\tau}-M_{\tau}}{M_{\tau}}\right) \quad (1)$$

$$RHS_{\tau} = D_{\tau}\left(\frac{P_{\tau}-M_{\tau+1}}{M_{\tau}}\right), \quad (2)$$

where P_{τ} is the execution price at the trading time τ, M_{τ} is the mid-quote at the same time. D_{τ} is the transaction direction indicator taking values 1, for buyer initiated transactions, and -1, for seller-initiated transactions, set according to [47]. The realized half-spread represents the compensation of the risk adverse liquidity supplier for bearing the price risk of an order imbalance [48]. $M_{\tau+1}$ is the mid-quote after the transaction, a proxy for the post-transaction value. The realized half-spread contains the non-informational component of the effective half-spread, i.e. the transaction cost net of the asymmetric information component. The informational, and permanent, component is measured by the price impact of a transaction (PI), defined as:

$$PI_{\tau} = D_{\tau}\left(\frac{M_{\tau+1}-M_{\tau}}{M_{\tau}}\right). \quad (3)$$

Effective half-spread, realized half-spread and price impact contribute to explain the costs of a single small transaction. However, liquidity adjusts to the pressure exerted by large transactions, often executed in multiple transactions [16]. In order to investigate this aspect in the NBP forward market, a second measure of price impact, from [16] [20], is adopted:

$$r_{n,t} = \lambda_n S_{n,t} + u_{n,t}, \quad (4)$$

where $r_{n,t}$ is the return time series over a fixed interval, t = 1,…,T in the rolling window n and $S_{n,t}$ is the sum of the signed square-root of the order flow in the interval and window. The time-varying coefficient, λ_n, is estimated assuming rolling windows of size m=4500 (two business years) over the sample and increments between successive rolling windows of 1 period. This results in 6031 estimates of the price impact λ (N=T-m+1, with T=12,870). The reciprocal of λ can measure market depth, where a low value of λ implies that prices are less sensitive to order flow.

IV. ESTIMATION AND EMPIRICAL RESULTS

Descriptive statistics of the daily liquidity measures are shown in Table I. On average, transaction costs in the NBP one month-ahead forward market are 0.312% (EHS), split in 0.171% of RHS and 0.141% PI. This implies that the non-informational component accounts for 55% of the EHS. The t-test computed on the difference between the EHS and PI is significant at 5% significance level. Nonparametric sign tests for the differences between medians and between quartiles of EHS and PI also reject equality. That is, the distributions of EHS and PI are significantly different. Figure 1 depicts the monthly medians of EHS, and suggests seasonal yearly pattern in the NBP one month-ahead forward market liquidity.

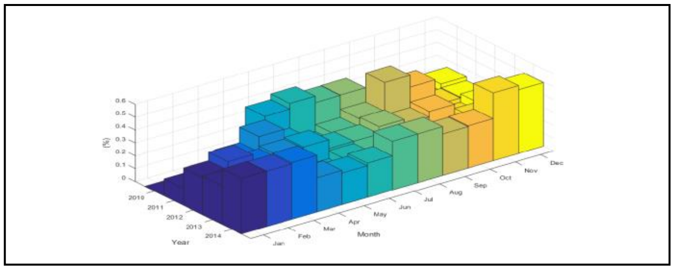

Figure 1 Monthly medians of EHS

TABLE I. DAILY LIQUIDITY MEASURES

Liquidity measure	Mean	St.Dev.	Q_{25}	Median	Q_{75}
EHS	0.312	0.223	0.170	0.259	0.395
RHS	0.171	0.186	0.076	0.143	0.240
PI	0.141	0.145	0.057	0.109	0.196

The table reports descriptive statistics of the daily time-weighted liquidity measures. For each measure, mean, standard deviation (St.Dev), lower quartile (Q_{25}), median and upper quartile (Q_{75}) are shown.

Table II reports the correlation between liquidity measures and trading activity variables. Correlation is high and positive between EHS and RHS (0.642), and EHS and PI (0.541), and lower but negative between RHS and PI (-0.160). Furthermore, correlation is positive between RHS and number of transactions and trading volume (0.145 and 0.163, respectively), and negative between PI and number of transactions and trading volume (-0.101 and -0.120, respectively).

Figure 2 shows the rolling estimates of the measure of price impact λ and estimated confidence intervals, based on the Newey-West autocorrelation and heteroscedasticity robust standard errors. A gradual decrease in the measure over the period up to March 2014 and an increase in level and variance in the subsequent period are observed.

Table III summarizes the distributions of daily liquidity measures in the pre- and post-REMIT periods; t-tests and a nonparametric sign tests on the means and medians, respectively, fail to reject equality in the pre- and post-event samples. One-tail F-tests reject the null hypothesis of equal variances across the two sub-samples for all the liquidity measures. There is higher volatility in EHS and RHS after REMIT.

Table IV reports estimates of the price impact measure λ in the pre- and post-REMIT periods. The Chow test rejects the null hypothesis of identical parameters across subsamples. Hence, there is a decrease in the price pressure exerted by the trading activity after REMIT.

TABLE II. SPEARMAN'S CORRELATION COEFFICIENTS BETWEEN LIQUIDITY MEASURES AND TRADING ACTIVITY VARIABLES

Variable	EHS	RHS	PI	No. Trans.
RHS	0.642**			
PI	0.541**	-0.160**		
No. Trans.	0.009	0.145**	-0.101**	
Trad. Vol.	0.011	0.163**	-0.120**	0.796**

The table reports Spearman's correlation coefficients between the effective half-spread (EHS), realized half-spread (RHS), price impact (PI), number of transactions (No. of Trans) and trading volume (Trad. Vol). ** denotes significance at 5%.

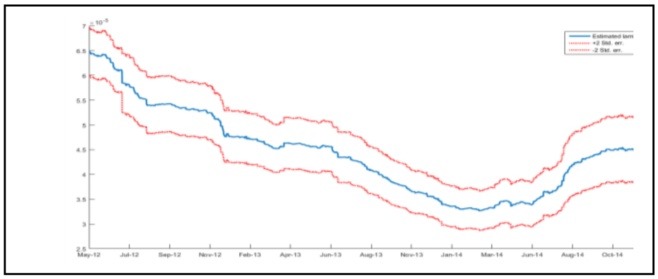

Figure 2 Rolling estimates of price impact measure λ

TABLE III. DAILY LIQUIDITY MEASURES IN THE PRE- AND POST-REMIT EVENT

Liquidity measure	Mean	St.Dev.	Q_{25}	Median	Q_{75}
Pre-REMIT, Obs.=413					
EHS	0.302	0.209	0.157	0.258	0.396
RHS	0.169	0.173	0.062	0.142	0.250
PI	0.140	0.160	0.045	0.111	0.194
Post-REMIT, Obs.=754					
EHS	0.317	0.230	0.177	0.260	0.395
RHS	0.173	0.193	0.083	0.144	0.236
PI	0.140	0.135	0.065	0.108	0.202

The table reports descriptive statistics of the daily time-weighted liquidity measures in the pre- and post-REMIT events. For each measure, mean, standard deviation (St. Dev), lower quartile (Q_{25}), median and upper quartile (Q_{75}) are shown.

VI. DISCUSSION AND CONCLUSIONS

From Table II, the higher and positive correlation between the effective half-spread and the realized half-spread in relation to the price impact measure, PI, suggests that changes in liquidity appear to be more associated with inventory costs than asymmetric information. This result is also supported by the higher and positive correlation between realized half-spread and trading activity. Hence, factors influencing inventory risk and order imbalances play an important role in explaining liquidity, with implications for hedging decisions likewise inventory decisions and storage value, being the natural gas a storable commodity.

It also appears that higher trading activity reduces liquidity in the NBP one-month ahead forward market. One possible interpretation of this finding would be that trading activity reduces dealers' inventory positions, thus increasing the cost of immediacy. This would be in line with the estimates of price impact, λ, which show a positive association between NBP one-month ahead forward price returns and order flow, thus corroborating previous findings from financial markets, e.g.[40]. Thus, the gradual decrease in this association over the period 2010-13 would imply lower immediacy cost and greater depth and resilience in the NBP one-month ahead forward market, possibly driven by lower demand and high inventory, which reduced trading activity in the period.

TABLE IV. PRICE IMPACT MEASURE Λ IN THE PRE- AND POST-REMIT EVENT

Event	Constant	λ	R2
Pre-REMIT	0.469** (0.235)	0.090***(0.01)	0.291
Post-REMIT	-0.228 (0.183)	0.076***(0.006)	0.228

The table reports estimate of the price impact measure λ in the pre- and post-REMIT events. ***, **, * denote 1%, 5% and 10% significance level, respectively. Standard errors are reported in brackets.

During 2013-14, NBP saw a drop in physical deliveries, in favor of the TTF hub [49] and a progressive shift of traders from the OTC to exchanges. Thus, in 2014, the premium of oil-linked contracts over hub prices in Continental Europe was a strong incentive for buyers to buy from hubs, in anticipation of higher volumes to be taken at lower oil-indexed prices, following the drop in oil-prices (July 2014). This likely behavior together with the gradual exit of investors from the commodities markets, observed since 2013, might have contributed to the increase in price pressure, and in turn to reduce liquidity during the second half of 2014.

No evidence of significant changes in liquidity after REMIT is found in the data, thus implying neither deterioration nor improvement in the competitiveness and efficiency of the NBP one-month forward market. However, the measures of spread and price impact indicate higher volatility since REMIT. Although increases in volatility may be reasonably explained by the decrease in the trading activity over the period, it may also reflect the lower frequency of investors in the market. Higher administrative costs may have not directly affected liquidity, but may have increased its variability.

The findings of this study are limited to the share of market here analyzed. Furthermore, the dataset does not discriminate between commercial and financial investors, thus the impact of REMIT on different trade types cannot be assessed. Nevertheless, the present study illustrates the usefulness of liquidity measures from financial markets to describe changes in liquidity in physical markets, in particular, natural gas markets. In this respect, the price impact measure, λ, has helped to link trading activity to price returns, thus enabling the assessment of the depth and resilience of the NBP one-month ahead forward market. Such aspects cannot be captured by the churn ratio, thus making this measure valuable to regulators when monitoring EU market quality, mainly after the disclosure of transaction data following REMIT.

ACKNOWLEDGMENT

We are grateful to Tullett Prebon Information, in particular to Abigail Lee and Matt Joy, for making the data available to this study. We would like to thank the reviewers for their useful comments.

References

[1] European Commission, "Proposal for a Directive of the European Parliament and of the Council on Markets in Financial Instruments Repealing Directive 2004/39/EC of the European Parliament and of the Council," Brussels, COM (2011) 656 final, Oct. 2011.

[2] European Commission, "Commission Staff Working Paper, Executive Summary of the Impact Assessment, Accompanying the Document Proposal for a Directive of the European Parliament and of the Council Markets in Financial Instruments and the Proposal for a Regulation of the European Parliament and of the Council Markets in financial instruments," Brussels, SEC (2011) 1227 final, Oct. 2011.

[3] J. de Larosière. "Final Report of the high-level group on financial supervision in the EU," Feb. 2009. Available: http://ec.europa.eu/internal_market/finances/docs/de_larosiere_report_en.pdf.

[4] M. W. Masters., and A. K. White. "The accidental hunt brothers: How institutional investors are driving up food and energy prices," Special Report, July 2008. Available: https://loe.org/images/content/080919/Act1.pdf.

[5] L. Nijman. "The impact of the new wave of financial regulation for European energy markets," *Energy Policy*, vol. 47, pp 468-477, 2012.

[6] H., Bessembinder, W.F. Maxwell, and K., Venkataraman, "Trading activity and transaction costs in structured credit products," *Financial Analysts Journal*, vol. 69, pp. 55-67, 2013.

[7] European Commission, 2004. Directive 2004/39/EC of the European Parliament and of the Council of 21 April 2004, on Markets in Financial Instruments Amending Council Directives 85/611/EC and 93/6/EEC and Directive 200/12/ EC of the European Parliament and of the Council and repealing Council Directive 93/22/EEC, OJ L 145, 30.4.2004.

[8] A. Madhavan, D. Porter, And D. Weaver, "Should securities markets be transparent?" *Journal of Financial Markets*, vol. 8, pp. 266–288, 2005.

[9] M. Cummins, and B. Murphy, "Natural gas markets and products," in *Handbook of Multi-Commodity Markets and Products*, A. Roncoroni, G. Fusai and M. Cummins, Ed. West Sussex: John Wiley & Sons Ltd, 2015, pp.135-180.

[10] European Commission,"Quarterly report on European gas markets," vol. 7 (issue 4; fourth quarter of 2014), 2015. Available: https://ec.europa.eu/energy/sites/ener/files/documents/quarterly_report_on_european_gas_markets_2014_q4.pdf.

[11] M. O'Hara. "Market microstructure theory," London: Blackwell, 1995.

[12] Y. Amihud, and H. Mendelson, "Asset pricing and the bid-ask spread," *Journal of Financial Economics*, vol. 17, pp. 223-249, 1986.

[13] M. J. Brennan, and A. Subrahmanyam, "Market microstructure and asset pricing: on the compensation for illiquidity in stock returns," *Journal of Financial Economics* vol. 41, pp. 441–464, 1996.

[14] T. Chordia, R. Roll, and A. Subrahmanyam, "Commonality in liquidity," *Journal of Financial Economics*, vol. 56, pp. 3-28, 2000

[15] L. Pastor, R.F., Stambaugh, "Liquidity risk and expected stock Returns," *Journal of Political Economy*, vol. 111, pp. 642-685, 2003.

[16] J. Hasbrouck, "Trading costs and returns for US equities: estimating effective costs from daily data," *Journal of Finance*, vol. 64, pp. 1445-1477, 2009.

[17] Ofgem. "Wholesale energy markets in 2015," 9 Sep. 2015. Available: https://www.ofgem.gov.uk/sites/default/files/docs/2015/09/wholesale_energy_markets_in_2015_final_0.pdf.

[18] J. Karpoff, "The relation between price changes and trading volume: A survey," *Journal of Financial and Quantitative Analysis*, vol. 22, pp. 109-127, 1987.

[19] R. Roll, "Recent research about liquidity," *Symposium on Finance, Banking and Insurance*, Universitä Karlsruhe (TH), 14-16 Dec., 2005. Available:http://www.fbv.kit.edu/symposium/10th/Key_Notes/Roll%20-%20Recent%20Research%20about%20Liquidity.pdf.

[20] A. Kyle, "Continuous auctions and insider trading," *Econometrica*, vol. 53(6), pp 1315–1335, 1985.

[21] R.Y. Goyenko, C. Holden and C. Trzcinka, "Do liquidity measures measure liquidity?" *Journal of Financial Economics*, vol. 92, pp. 153-181, 2009.

[22] H. R. Stoll, "The supply of dealer services in security markets," *Journal of Finance*, vol. 33, pp. 1133-1151, 1978.

[23] R. Roll, "A simple implicit measure of the effective bid-ask spread in an efficient market," *Journal of Finance*, vol. 39, pp. 1127-1139, 1984.

[24] H. Bessembinder, "Bid-ask spreads in the interbank foreign exchange markets," *Journal of Financial Economics*, vol. 35, pp. 317-348, 1994.

[25] H. Bessembinder, "Issues in assessing trade execution costs," *Journal of Financial Markets*, vol. 6, pp. 233-257, 2003.

[26] T. Foucault, M. Pagano and A. Röell, Market liquidity, Oxford University Press, 2013.

[27] H. Demsetz, "The cost of transacting," *Quarterly Journal of Economics*, vol. 82, pp. 33-53, 1968.

[28] H. Stoll, "Inferring the components of the bid-ask spread: Theory and empirical tests," *Journal of Finance*, vol. 44, pp. 115-134, 1989.

[29] H. Bessembinder, and K. Venkataraman, "Bid-ask spreads: Measuring trade execution costs in financial markets". In *Encyclopedia of Quantitative Finance*, Rama Cont, Ed. John Wiley & Sons Ltd, 2010.

[30] S.A. Corwin, and P. Schultz, "A simple way to estimate bid-ask spreads from daily high and low prices," *Journal of Finance*, vol. 67, pp. 719 – 759, 2012

[31] K. Y. L. Fong, C. W. Holden, and C. Trzcinka, "What are the best liquidity proxies for global research?", July 16, 2014. Available: http://ssrn.com/abstract=1558447 (accessed on 27/01/2016).

[32] P. Locke, and P. Venkatesh, "Liquidity commonality in commodities," *Journal of Future Markets*, vol. 17, pp. 229-245, 1997.

[33] B. Marshall, N. Nguyen, and N. Visaltanachoti, "Commodity liquidity measurement and transaction costs," *Review of Financial Studies*, vol. 25, pp. 599-638, 2012.

[34] B. Marshall, N. Nguyen, and N. Visaltanachoti, "Liquidity commonality in commodities," *Journal of Banking & Finance*, vol. 37, pp. 11-20, 2013.

[35] D. Frestad, "Liquidity and dirty hedging in the Nordic electricity market," *Energy Economics*, vol. 34, pp. 1341-1355, 2012.

[36] V.V. Acharya, and L.H. Pedersen, "Asset pricing with liquidity risk," *Journal of Financial Economics*, vol. 77, pp. 375-410, 2005.

[37] C. Banti, K. Phylaktis, and L. Sarno, "Global liquidity risk in the foreign exchange market," *Journal of International Money and Finance*, vol. 31, pp. 267-291, 2012.

[38] S. Chen, C. Chih-Chung, and C. Ming-Jen, "Order flow, bid–ask spread and trading density in foreign exchange markets," *Journal of Banking and Finance*, vol. 36, pp. 597-612, 2012.

[39] M. D.D. Evans, "Order flows and the exchange rate disconnect puzzle," *Journal of International Economics*, vol. 80, pp. 58-71, 2010.

[40] R. Payne, "Informed trade in spot foreign exchange markets: an empirical investigation," *Journal of International Economics*, vol. 61, pp. 307-329, 2003.

[41] C. Brownlees, and G. Gallo, "Financial econometric analysis at ultra high frequency: Data handling concerns," *Computational Statistics and Data Analysis*, vol. 51, pp. 2232-2245, 2006.

[42] O. Barndorff-Nielsen, P. Hansen, A. Lunde, and N. Shephard, "Realised kernels in practice: Trades and quotes," *Econometrics Journal*, vol. 12, pp. 1-33, 2009.

[43] L. Zhang, "Estimating covariation: Epps effect, microstructure noise," *Journal of Econometrics*, vol. 160, pp. 33-47, 2011.

[44] S. Boffelli and G. Urga, "Macroannouncements, bond auctions and rating actions in the European government bond spreads," *Journal of International Money and Finance*, vol. 53, pp.148-173, 2015.

[45] R. Engle, "The econometrics of ultra-high frequency data," *Econometrica*, vol. 68 (1), pp. 1-22, 2000.

[46] T. Chordia, A. Sarkar, and A. Subrahmanyam, "An empirical analysis of stock and bond market liquidity," *Review of Financial Studies*, vol. 18, pp. 85–129, 2005[47] C. Lee, Cand M., Ready, "Inferring trade direction from intraday data," *Journal of Finance*, vol. 46, pp. 733-746, 1991.

[47] C. Lee, M. Ready, "Inferring trade direction from intraday data," *Journal of Finance*, vol. 46, pp. 733-746, 1991.

[48] Y. Amihud, and H., Mendelson, "Dealership market: Market-making with inventory," *Journal of Financial Economics*, vol. 8, pp. 31-53, 1980.

[49] European Commission, Quarterly Report on Gas Q12015, 2015. Available:https://ec.europa.eu/energy/sites/ener/files/documents/quarterly_report_on_european_gas_markets_q1_2015.pdf.