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Relationship between Liquidity, Volatility and Trading Activity: An Intraday Analysis of Indian Stock Market

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ABSTRACT

The liquidity crunch arising out of volatile market conditions is a significant concern for investors across the globe. The trading activity in the market is an important attribute determining the liquidity as well as the volatility of any stock market. Given this triangular relationship, this study analyzes the relationship between liquidity, volatility and trading activity in the Indian stock market. Employing ordinary least squares regression estimates, the study identifies a contraction in liquidity in response to greater trading activity which is found to be increasing volatility in the market. It finds that higher volatility in Indian market is associated with greater illiquidity in the market. Even after adjusting for the impact of trading activity, volatility is found to be exhibiting a statistically significant impact on liquidity.

Keywords: Indian Stock Market, Intraday Liquidity, Ordinary Least Square Regression, Trading Activity, Volatility
JEL Classifications: C1, G11, G12

1. INTRODUCTION

The liquidity of a stock market indicates the occurrence of larger volumes of trade within the shortest possible time and with the least possible cost of transaction. It is regarded that a liquid market is characterized by high volume, remaining other dimensions of liquidity being constant. The market microstructure theory provides that the markets with higher volumes will be less volatile. Thus, from the traditional market microstructure theories it can be derived that a liquid market will have larger volumes of trade and thus less volatile. From this triangular relationship, it can be revealed a theoretically supported inverse relationship between liquidity and volatility, indicating that a greater volatility may result in lessening the liquidity of a stock market and vice versa. Emphasizing this relationship, the literature identifies a severe liquidity crunch associated with increased volatility that led to the global financial crisis and the spread of contagion effects to the markets across the globe during 2007-2009. Given this, the literature has widely attempted to comprehend the relationship between liquidity, volatility and trading activity in different markets.

The inverse relationship is predicted between volatility of returns and the liquidity in the market microstructure theories are based on the assumption that the market-makers bear a greater inventory risk for holding a highly volatile security. There are empirical studies confirming this relationship by exhibiting a positive relationship between the volatility in returns of a security and its illiquidity (Amihud and Mendelson, 1989; Foster and Viswanathan, 1990; Stoll, 2000). However, the literature offers certain contradictory empirical evidence as well.

There are two broad categories of liquidity models establishing the relationship between liquidity of an asset and the volatility in its returns viz. inventory models and information-based models. The inventory model predicts an inverse relationship between liquidity of an asset and the volatility in its returns. On the other hand, the information-based model envisages that it can either be positive or negative. For instance, Barclay and Warner (1993) reveals a direct relationship between liquidity and volatility, indicating higher volatility associated with greater liquidity, in informed stealth trading, where majority of traders are uninformed. Inconsistently, the literature also advocates that professionals' acquaintance regarding the existence of informed traders can cause an inverse relationship between the duos (Foster and Viswanathan, 1990). Thus, the empirical analysis gives two different results like a positive relationship between volatility and liquidity identified by Stoll (1978), Stoll (2000), and Menyah and Paudyal (1996), whereas Pastor and Stambaugh (2001) offers that the correlation between market-wide liquidity and volatility is negative.

Establishing the relationship between trading volume and volatility, Darrat et al. (2003) and Huang and Masulis (2003) show that at the firm level, the trading volume moves in tandem with volatility i.e., an increase in trading volume is associated with an increase in return volatility. This contradicts with the traditional market microstructure establishment of lesser return volatilities associated with larger volumes of trade.

With regard to the relationship between liquidity and trading volume, Stoll (2000) and Wu and Guo (2004) account trading volume as among the most persuasive elements of bid-ask spread of an individual security. Goldstein and Nelling (1999) show that the volume of transactions motivated to ensure liquidity among other variables viz., competition among market-makers, and the quality of disseminated public information act as a determinant of spread. However, Brock and Kleidon (1992) predicts wider bid-ask spreads (lesser liquidity) associated with high trading volume.

The review of available literature reveals that even though there is good number of studies analyzing the intraday relationships among liquidity, volatility and trading activity at security level, there lacks clarity in such intraday relationships at an aggregate market level, despite of the importance of such relationships in assessing the liquidity and volatility conditions of the market. Therefore, this study aims at empirically analyzing the relationship between liquidity, volatility and trading activity at an aggregate market level. It also attempts to explore the overall market behaviour established by the interactions among intraday volatility in returns and the market-wide liquidity employing activity-adjusted volatility variables in augmented econometric models.

2. DATA AND METHODOLOGY

The study aims at analyzing the intraday interactions among liquidity, volatility in returns and trading activity, and thus demands for the use of intraday data. It employs intraday, 1-min trade and quote data of 50 securities forming part of the most dynamic stock market index of India, NIFTY 50 Index. The data collected covers a period from January 1, 2016 to December 31, 2016. There were 246 trading days during the period of study. In national stock exchange of India Ltd., the regular trading session opens at 9:15 AM and closes at 3:30 PM, the Indian standard time (IST). This study considers minute-by-minute data from 9:16 AM to 3:29 PM consisting of 374 1-min intervals. The 246 trading days with 374 observations contributes to 92,004 observations per security.

The trade and quote data considered in the study includes the trade price, bid price, ask price, quantity traded, quantity bided, quantity asked, number of trades occurred, number of trades bided and number of trades asked in every minute of the trading day. From these data, the study quantified 9 intraday, minute-by-minute liquidity measures covering the cost and multidimensional aspects of liquidity. The cost dimensional measures include quoted spread (S_t), proportional quoted spread (PS_t), effective spread (ESPR) and proportional ESPR (PESPR). The multidimensional liquidity measures include quote slope (QS_t), log QS_t ($LnQS_t$), composite liquidity (CL_t), Amihud measure (AMR), and flow ratio (FR). Each liquidity measure is averaged across the trading days for every 1-min time interval for any given stock to arrive at an average 1-min liquidity measure for that particular security. This gives 374 1-min averaged observations for each measure of liquidity. An intraday aggregate market-wide measure is arrived at for each liquidity measure by averaging the 1-min observations for a given measure across the fifty securities by employing equal weight. These measures are brought into a principal component analysis (PCA) framework to get more comprehend measures of liquidity possessing all the characters of the dimension of liquidity they represent. PCA is carried out for the cost dimensional and multidimensional liquidity measures. Based on the results of PCA, by employing the coefficients of first principal components new measures of liquidity are derived for each dimension resulting in two new measures viz., spread, and a multidimensional measure.

The intraday 1-min returns are calculated for each security and are averaged across the trading days to arrive at average intraday 1-min returns of each security. The trading volume and the number of transactions (N_t) are considered as measures of trading activity. They are averaged across the number of trading days to arrive at intraday trading activity and intraday N_t for each security.

The intraday 1-min returns, the intraday trading volume and the intraday N_t are averaged across fifty securities to derive intraday market return, intraday market-wide trading volume (Q_t), and intraday market-wide N_t, respectively. The intraday market return series is brought to a GARCH (1, 1) model and the residuals are derived as the market volatility variable (VOL).

The ordinary least square (OLS) model regressions are carried out to examine the relationship between market-wide liquidity, volatility and trading activity.

3. THE RESULTS OF PCA

Tables 1 and 2 report the results of PCA. Table 1 shows the results of PCA on the cost dimensional measures of liquidity that includes quoted spread (S_t), PS_t, ESPR and PESPR. The results indicate that the first principal component alone explains around 59.70% variations in these four intraday cost dimensional measures with eigenvalue >1. Based on this result, a new variable is derived from the principal component 1 as the measure of cost dimension of liquidity which is named as SPREAD.

Table 2 exhibits the results of PCA on the multidimensional measures of liquidity viz., QS_t, log QS_t ($LnQS_t$), CL_t, AMR, and

Table 1: PCA: S_t, PS_t, ESPR, PESPR

Eigen analysis of the correlation matrix				
Eigenvalue	2.3886	0.7792	0.4749	0.3573
Proportion	0.597	0.195	0.119	0.089
Cumulative	0.597	0.792	0.911	1
Eigenvectors				
Variable	PC1	PC2	PC3	PC4
S_t	0.519	0.213	−0.801	−0.208
PS_t	0.436	0.731	0.51	−0.125
ESPR	0.55	−0.252	0.084	0.792
PESPR	0.487	−0.597	0.303	−0.561

ESPR: Effective spread, PESPR: Proportional ESPR, PCA: Principal component analysis

Table 2: PCA: QS_t, $LnQS_t$, CL_t, AMR, FR

Eigen analysis of the correlation matrix					
Eigenvalue	2.7363	0.9437	0.7747	0.5408	0.0046
Proportion	0.547	0.189	0.155	0.108	0.001
Cumulative	0.547	0.736	0.891	0.999	1
Eigenvectors					
Variable	PC1	PC2	PC3	PC4	PC5
QS_t	0.416	0.395	0.259	-0.777	0.001
$LNQS_t$	0.559	-0.069	-0.407	0.128	-0.707
CL_t	0.559	-0.077	-0.408	0.125	0.707
AMR	0.234	-0.859	0.422	-0.171	-0.004
FR	0.383	0.308	0.65	0.579	0.003

QS_t: Quote slope, $LNQS_t$: Log QS_t, CL_t: Composite liquidity, AMR: Amihud measure, FR: Flow ratio

FR. It provides that the principal component 1 explains almost 54.70% of the characteristics of all the five individual measures covering multidimensional aspect of liquidity with Eigenvalue >1. Thus, the study employs only the variable derived from this principal component for further analysis and the new component is named as MDLIQ, indicating multidimensional measure of liquidity.

3.1. Pearson's Correlation Coefficients

To explore the basic relationship between the variables used in the analysis, a correlation matrix is generated. The correlation matrix presented in Table 3 shows that all the variables are exhibiting positive correlations. It provides a broad picture of possible relationship between liquidity, volatility and trading activity.

3.2. Relationship between Trading Activity and Liquidity

Relationship between trading activity and liquidity is explored through regressing independently the measures of liquidity viz., SPREAD, and MDLIQ with proxies of trading activity namely N_t and trading volume (Q_t). The regression equation is as follows:

$$SPREAD_t = \beta_0 + \beta_1 ACTIVITY_t + e_t \quad (1)$$

$$MDLIQ_t = \beta_0 + \beta_1 ACTIVITY_t + e_t \quad (2)$$

where, the N_t or trading volume (Q_t) is expressed as $ACTIVITY_t$.

Table 4 presents the coefficients of OLS regressions by considering measures of liquidity as dependent variable and proxies of trading activity as independent variable. Panel A in the Table shows the estimates for SPREAD and MDLIQ regressed with trading activity as measures by the N_t. Panel B provides the regression estimates of the liquidity measures on the trading activity of the market as measured by trading volume (Q_t).

Table 3: Correlation matrix

	SPREAD	MDLIQ	Q_t	N_t
MDLIQ	0.69536			
Q_t	0.60526	0.57877		
N_t	0.63788	0.47752	0.83508	
VOL	0.17449	0.19985	0.30521	0.21809

N_t: Number of transactions, VOL: Volatility variable

Table 4: Coefficients of regression by considering measures of liquidity as dependent variable and proxies of trading activity as independent variable

Panel A: N_t as the proxy for trading activity			
Liquidity measure	**Constant**	**N_t**	**R^2**
SPREAD	0.0565	0.02850	0.1057
	(9.2443)	(7.2862)	
MDLIQ	0.0032	0.0566	0.1446
	(10.9625)	(4.4121)	
Panel B: Trading volume (Q_t) as the proxy for trading activity			
Liquidity measure	**Constant**	**Q_t**	**R^2**
SPREAD	0.0517	0.0145	0.1136
	(9.8327)	(6.5541)	
MDLIQ	0.0274	0.01190	0.1598
	(9.2529)	(2.8283)	

N_t: Number of transactions,

Panel A of the Table shows that trading activity as measured by N_t is positively influencing both the liquidity measures, indicating that an increase in the N_t results in an increase in SPREAD as well as MDLIQ. However, such corresponding increases in these measures are demonstrating lesser liquidity in the market. It shows that as the N_t increases, the SPREAD widens and thus resulting in greater transactions costs for the common investors. As the MDLIQ, being a multidimensional measure, also exhibit similar relationship, it can be concluded that the higher volumes are associated with lesser liquidity in Indian stock market.

Panel B of the table confirms such inverse relationship by showing similar result for the relationship between liquidity as measured by SPREAD and MDLIQ and trading volume (Q_t) as proxy for trading activity. Thus, these results confirms the similar U-shaped patterns in the cost, quantity, time as well as multidimensional measures of liquidity and proves an inverse relationship between liquidity and trading volume as provided by Brock and Kleidon (1992).

Another possible insight from the result is that the multidimensional measure, MDLIQ exhibits stronger interaction with both trading activity measures as expressed by its R^2 values, compared to the traditional, cost-dimensional measure (SPREAD).

The results from Table 4 are of utmost significance for the common investors. This is because of the caution offered by these results that the transaction costs are not reducing in response to the increase in trading volumes in Indian stock market. There are possibilities of existence of hidden costs arising out of inventory risk, asymmetric information or order processing aspects contributing to such inverse relationships, and increasing the cost of transacting in the market even when the trade occurs in large quantities and within shorter time periods, yet needs empirical confirmation.

3.3. Relationship between Trading Activity and Volatility

In order to analyse the relationship between trading activity and volatility, the study regressed the market return volatility as estimated from GARCH (1, 1) model with the trading activity proxies viz., N_t and trading volume (Q_t). The following regression equation is employed:

$$VOL_t = \beta_0 + \beta_1 ACTIVITY_t + e_t \quad (3)$$

The estimates of the OLS regressions considering volatility of returns as dependent variable and proxies of trading activity as independent variable are presented in Table 5.

Table 5 reveals that the return volatility in Indian stock market moves in tandem with the trading activity in the market as the coefficients of both the proxies of trading activity express a positive and statistically significant relationship with stock market volatility. It indicates that when huge volumes of trade occurs in the market as demonstrated by trading volume (Q_t) within shorter time spans as measured by N_t, the Indian stock market is tend to be more volatile. Thus, in line with the information-based liquidity theories and the stealth trading hypothesis of Barclay and Warner (1993), this study confirm the results of others that more buying and selling in the market reveals information about the market due to trading activities, which in turn makes market more volatile. In other words, increased volumes of trade, increasing the N_t per unit time cautions the common investors about the presence of bulk traders, who can be either informed traders, algorithmic traders or FIIs entering into the market to make the best possible advantage of the information they possess. Once the effect of the information gets lapses they tend to counter react as well. The disproportionate trading activity arising out of such actions and counter reactions makes the market more volatile. Thus, it is suggestive that the higher trading activity in Indian stock market is a not a stable phenomenon and associated with increased volatility in returns. And therefore, it is advised to common investors not to respond to the increased trading activities in the market resulting in temporary intraday peaks in the market indices which are not lasting in nature.

3.4. Relationship between Volatility and Liquidity

The empirical literature identifies price, trading activity, and volatility as most important determinants of liquidity (Tinic, 1972; Menyah and Paudyal, 1996). Attempting to comprehend such influences in Indian stock market, the market-wide liquidity, measured in terms of SPREAD and MDLIQ, indicating the cost dimensional and multidimensional aspects of liquidity respectively, are regressed on the market return volatility (VOL) taking the following form.

$$SPREAD = \beta_0 + \beta_1 VOL_t + e_t \quad (4)$$

$$MDLIQ = \beta_0 + \beta_1 VOL_t + e_t \quad (5)$$

Table 6 reports the results of relationship between volatility and liquidity as measured by SPREAD and MDLIQ. The results indicate that volatility is exhibiting positive influence on the measures of liquidity considered in the study. However, these are essentially the measures of illiquidity rather than liquidity in such a way that an increase in these measures indicates a reduction in the market liquidity. For instance, consider the SPREAD. A higher value of SPREAD denotes wider spreads contributing to an increase in the transaction costs. MDLIQ is also providing similar insights. Thus the displayed significant positive relationship is essentially between volatility (VOL) of market returns and the market illiquidity indicating that an increase in volatility makes the market more illiquid and the lower volatility of market returns are associated with narrower spreads and lesser transaction costs for the investors. Chordia et al. (2001) documented a similar result revealing the association of higher volatility with a lower spread as well as trading activity in the New York stock exchange. Reading these results with the significant positive association between volatility of market returns and trading activity exhibited in Table 5, it can be concluded that the increased trading activities happening in Indian stock market makes the market more volatile on the account of possible asymmetric information which in turn results in lesser liquidity in the market where the common investors who are largely uninformed are forced to incur more transactions cost and thus kept away from the benefits of quantity and time dimensions of liquidity. This reveals the imperfections in Indian stock market.

3.5. Impact of Trading Activity on the Relationship between Liquidity and Volatility

Controlling for the influence of trading activity on volatility of returns at market-level, this study also estimates the impact of trading activity on liquidity – volatility relationship. The volatility is standardized to the extent of trading activity expressed as number of trades and trading volume in order to capture volatility per unit of trading activity, facilitating the removal of the impact of trading activity variables on volatility of market returns. Employing each company's market capitalization as weight, an intraday market-wide index of trading volume is constructed

Table 5: Coefficients of regression by considering volatility of returns as dependent variable and proxies of trading activity as independent variable

Trading activity measure	Constant	Activity	R^2
Number of transactions (N_t)	0.01969	0.001017	0.3851
	(6.1694)	(4.3279)	
Trading volume (Q_t)	0.02521	0.00263	0.3012
	(5.6479)	(6.9839)	

Table 6: Coefficients of regression by considering proxies of liquidity as dependent variable and volatility of returns as independent variable

Liquidity measure	Constant	VOL	R^2
SPREAD	0.1248	0.3244	0.01826
	(49.7708)	(1.8715)	
MDLIQ	0.13205	0.24543	0.13012
	(7.8787)	(4.6714)	

Table 7: Coefficients of regression by considering proxies of liquidity as dependent variable and adjusted volatility of returns as independent variable

Panel A: Number of transactions-adjusted volatility			
Liquidity measure	**Constant**	**ADJVOLNT**	**R^2**
SPREAD	0.1548 (49.9135)	1.0526 (6.8277)	0.05181
MDLIQ	0.19360 (48.1850)	1.12566 (9.9357)	0.19103
Panel B: Volume of trade-adjusted volatility			
Liquidity Measure	**Constant**	**ADJVOLVO**	**R^2**
SPREAD	0.14538 (49.6931)	1.90149 (10.7632)	0.09165
MDLIQ	0.21930 (48.1649)	2.00147 (10.8439)	0.21078

ADJVOLNT and ADJVOLVO indicate the volatility adjusted for the effects of trading activity as proxied by N_t and volume of trades respectively

using weighted average of volume of trade of individual stocks. The volatility as estimated by the GARCH (1, 1) model is then divided by the intraday market-level index of trading volume. The liquidity measures SPREAD and MDLIQ are then regressed with the trading volume- or N_t- adjusted market VOL (ADJVOL) using the following equation:

$$SPREAD = \beta_0 + \beta_1 ADJVOL_t + e_t \tag{6}$$

$$MDLIQ = \beta_0 + \beta_1 ADJVOL_t + e_t \tag{7}$$

Table 7 shows that the volatility adjusted for the effects of trading activity has a statistically significant impact on both liquidity measures. It is found that the MDLIQ is exhibiting a stronger association with the volatility adjusted by N_t as well as trading volume. This confirms that it is the cost dimension dominating the determination of liquidity in Indian stock market.

Comparing the results of interaction among liquidity and volatility presented in Table 6 and 7, it can be inferred that even after removing or controlling the effect of trading activity the volatility of market returns in Indian stock market are significantly influencing the liquidity of the market. The liquidity rather exhibits an aggressive association with the volatility of market returns in Indian stock market. For instance, one unit increase in volatility-adjusted for volume of trade (ADJVOLVO) leads to >200% increase in MDLIQ. It can be inferred from this that even a minute increase in the volatility of market returns will result in significant drain out of liquidity of the market.

Thus, the results offer robust evidence that there exists a positive relationship between illiquidity and volatility, controlling for trading activity, as established in information theories of asset pricing dynamics. This result can be very well related to the global financial crisis of 2008, in which Indian stock market also felt the contagion effects, in such a way that it was the crisis caused from volatility of market returns leading to a severe liquidity crunch in the market and subsequent collapse of many global economies.

4. CONCLUSION

The relationship between liquidity and volatility of a stock as well as the market as a whole is an area of immense attention among academicians and practitioners in finance on account of its importance on investment decisions. An inverse relationship between the volatility and liquidity of assets is predicted by market microstructure theories. It is further supported by empirical studies at individual stock level. However, the empirical results are contradictory at market level. This study attempted to analyze the relationship between liquidity and volatility at market level employing intraday data. It further tried to examine the impact of trading activity as measured by N_t and trading volume on the relationship between liquidity and volatility.

The study finds a significant contraction in market liquidity associated with higher trading activity. A similar relationship is found between market-wide liquidity and volatility in market returns. The study also examined the relationship between volatility and trading activity and documented that volatility is positively influencing the trading activity in Indian stock market indicating that an increase in trading activity results in an increase in volatility of returns in the market. From these relationships, it can be summarized that there is a reduction in market liquidity associated with higher trading activity in the market which may be induced by asymmetric information that contributes to significant increase in volatility of market returns which leads to further reduction of liquidity in Indian stock market.

This study also attempted to document the relationship between volatility which is adjusted for the influence of trading activity and market-wide liquidity, in order to identify whether the relationship between volatility and liquidity established in Indian stock market is arising merely out of the positive relationship between volatility and trading activity. It finds that the market liquidity is more responsive to volatility of market returns in Indian stock market when the effect of trading activity is controlled. It documents that the market liquidity exhibits an aggressive relationship with volatility of returns in such a way that even a minute change in volatility contributes to a significant fluctuation in market liquidity.

Thus, it can be concluded that the established interaction between liquidity, volatility and trading activity in the market gives a caution to the common investors that it is not the quantity or time elements determine the liquidity in Indian stock market. Rather, it is the cost dimension which affects the stock market liquidity in India. This cost dimension of liquidity holds significant inverse relationship between volatility as well as trading activity in the market. Hence, the investor needs to understand that the higher volumes of trade are often leads to greater transaction costs and therefore, lesser liquidity. Similarly, when the market is exhibiting significant volatility in returns, it has to be considered as an indication of severe liquidity crunch which is on its way.

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