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Abstract

This paper aims to establish trends in intraday volatility in context of the Indian stock market and

analyze the impact of development in the Indian economy on its stock market volatility. One

minute tick data of Nifty 50 futures from Jan 1, 2011 to Aug 31, 2018 was used for the purpose

of this research. Volatility was computed for each day of week and various time intervals. Our

analysis shows evidence of the expected U-shaped pattern of intraday volatility (higher at the

beginning and end of the day). We also observed a decline in the hourly volatility over the time

period studied. However, sufficient evidence to determine the impact of development in the

Indian economy on volatility in the stock market was not found.

1. Introduction

Volatility is defined as the measure of the dispersion around the mean/expected return of a security. A greater degree of volatility means there is a higher likelihood of large price movements which increases the risk and uncertainty associated with owning a security. According to study on the S&P 500 by Crestmont Research (2017), periods of high volatility correspond to a greater likelihood of a declining market while lower volatility is associated with a rising market. This makes it important for investors and stock traders to keep regular track of the volatilities of their portfolios.

While several studies have shown that developing economies have a more volatile stock market than their more developed counterparts (Agarwal, Inclan, & Leal, 1999; Bekaert & Harvey, 1997; Santis & Imrohoroglu, 1997), little research exists to analyze how volatility in a country's stock market changes as its economy and financial institutions develop over time. This paper analyzes this relationship by considering volatility in the Indian stock market. India has two major stock exchanges – the National Stock Exchange (NSE) and Bombay Stock Exchange (BSE) – with market capitalizations of US$2.273 trillion and US$2.298 trillion respectively as on 30 April, 2018 (The World Federation of Exchanges, 2018).

For the purpose of this study, the time period considered is from Jan 1, 2011 to Aug 31, 2018. Time after Jan 1, 2011 was considered mainly for two reasons. First, it was felt this was sufficiently distanced from the 2008 financial crisis to negate its impact on volatility in the market. Secondly, the pre-opening auction session to reduce volatility at opening was introduced by the NSE and BSE from Oct 18, 2010 (The Hindu, 2010). This changed the timings of both bourses to 9:15 am to 3:30 pm. Over the same period, the Gross Domestic Product (GDP) of India increased from US$1.766 trillion in 2011 to US$2.629 trillion in 2017 – an annual compounded increase of

6.854% (The World Bank, 2018). Furthermore, the value of the Human Development Index (HDI) of India increased from 0.547 in 2011 (United Nations Development Programme, 2011) to 0.640 in 2017 (United Nations Development Programme, 2018). The increase in both of these factors – considered measures of a country's development – indicates that India has developed since 2011. This development allows us to test the hypothesis that more developed countries have lower stock market volatility.

While both the NSE and BSE have almost a similar total market capitalization as mentioned above, the annual turnover in the spot market for FY 2017-18 was ₹72.348 trillion for the NSE but only ₹10.830 trillion for the BSE (Reserve Bank of India, 2018). Moreover, while the equity derivative turnover for FY 2017-18 was ₹1653.060 trillion for the NSE, it was only ₹32.6 billion for the BSE (Reserve Bank of India, 2018). This higher trading activity and consequent greater information about the NSE led us to select it for the purpose of analyzing trends in volatility in the Indian stock market.

2. Data and Methodology

The data used to calculate volatility in the NSE is the National Stock Exchange Fifty index (Nifty 50), which is a free float market capitalization weighted index of 50 Indian companies in 12 sectors. It is NSE's benchmark broad based stock market index for the equity market and represents 62.9% of the free float market capitalization of all stocks listed on the NSE (National Stock Exchange of India Ltd., 2017). It is also the world's most actively traded contract. This immense attention and tracking by market participants that Nifty 50 enjoys has led to the easy availability of its historical data publicly.

One minute intraday tick data of Nifty futures from Jan 1, 2011 to Aug 31, 2018 was used in the study. Intraday data was used for the purpose of the study as it gives us a more accurate depiction of volatility and enables us to establish intraday trends (such as the expected U-shaped pattern) of volatility in context of the Indian stock market. 7 Saturdays between 2012 and 2014 – when the market was closed due to special sessions to check failover systems – were removed from the sample. Muhurat trading[1] sessions were also removed from the sample.

In this study, we calculated the all-day volatility and intraday volatility for various time intervals. To calculate the all-day volatility, first the percentage returns corresponding to each minute over the previous minute were calculated. Next, the data was segregated according to what day of the week the trading day fell on. Then for each day, the intraday volatility was calculated for each distinct date and the arithmetic mean of all the figures was calculated to arrive at the all-day volatility of a particular day of a week. This per-minute figure was then converted into hourly by multiplying it with a factor of $\sqrt{60}$. This is given in Table 1 later for the duration from Jan 1, 2011 to Aug 31, 2018.

To determine volatility in individual time periods (such as 9:15 to 10:00 or 12:00 to 13:00), the data of distinct days obtained earlier was further divided according to the time period, and volatility was calculated for those figures having similar days and time intervals but different dates. Then, the arithmetic mean of these volatility figures was measured to arrive at the volatility for different time periods on separate days of the week. The resulting numbers were then multiplied by a factor of $\sqrt{60}$ to determine the hourly volatility for the same. This is also given in Table 1 later for the duration from Jan 1, 2011 to Aug 31, 2018.

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[1] Muhurat trading refers to trading activity in the Indian stock market on the auspicious occasion of Diwali, a major festival in India. See https://en.wikipedia.org/wiki/Muhurat_trading for more information.

Similar analysis was undertaken to calculate the intraday volatility for individual years from 2011 to 2018. This enabled us to determine trends in volatility over the years as shown later in Tables 2-9.

3. Empirical Evidence

As seen in Table 1 below, intraday volatility of the Nifty 50 follows the expected U-shaped pattern over the course of a day – it is higher at the beginning and the end of the day. The time between 11:00 and 12:00 was found to exhibit the lowest volatility in the duration from 2011 to 2018. These findings of an U-shaped intraday volatility pattern are in line with previous finance literature (Admati & Pfleiderer, 1988; Becker, Finnerty, & Kopecky, 1993; Andersen, Bollerslev, & Ashish, 2001; Cyree, Griffiths, & Winters, 2004; Wang, Yamasaki, Havlin, & Stanley, 2006; McMillan & Speight, 2006).

Table 1
Intraday volatility converted from per minute to hourly – 2011 to Aug. 2018 (in %)

Day	Hour							
	All-day	9:15 – 10:00	10:00 – 11:00	11:00 – 12:00	12:00 – 13:00	13:00 – 14:00	14:00 – 15:00	15:00 – 15:30
MON	0.2770	0.3459	0.2329	0.2147	0.2405	0.2680	0.3053	0.2558
TUE	0.2883	0.3360	0.2405	0.2319	0.2458	0.2838	0.3242	0.2696
WED	0.2828	0.3258	0.2352	0.2211	0.2424	0.2810	0.3241	0.2727
THU	0.2854	0.3160	0.2300	0.2185	0.2402	0.2883	0.3317	0.3081
FRI	0.3248	0.4244	0.2515	0.2378	0.2613	0.3039	0.3486	0.2931
AVG.	0.2917	0.3496	0.2380	0.2248	0.2460	0.2850	0.3268	0.2799

While the volatility was mostly similar for different days of the weeks, Friday displayed the highest volatility among others. One possible reason for this anomaly could be heightened market activity by investors due to lack of control over financial, political and economic events while markets remain closed over the weekend.

Table 2
Intraday volatility converted from per minute to hourly – 2011 (in %)

Day	Hour							
	All-day	9:15 – 10:00	10:00 – 11:00	11:00 – 12:00	12:00 – 13:00	13:00 – 14:00	14:00 – 15:00	15:00 – 15:30
MON	0.4242	0.4768	0.3695	0.3791	0.3930	0.4089	0.4626	0.3718
TUE	0.4191	0.4697	0.3595	0.3695	0.3691	0.4286	0.4726	0.4049
WED	0.4090	0.4260	0.3436	0.3525	0.3845	0.4243	0.4598	0.3745
THU	0.4132	0.4195	0.3302	0.3448	0.3645	0.4382	0.4783	0.4449
FRI	0.4632	0.4942	0.3814	0.3956	0.4092	0.4591	0.5283	0.4483
AVG.	0.4257	0.4572	0.3568	0.3683	0.3841	0.4318	0.4803	0.4089

Table 3
Intraday volatility converted from per minute to hourly – 2012 (in %)

Day	Hour							
	All-day	9:15 – 10:00	10:00 – 11:00	11:00 – 12:00	12:00 – 13:00	13:00 – 14:00	14:00 – 15:00	15:00 – 15:30
MON	0.2884	0.3688	0.2227	0.2482	0.2420	0.2747	0.3090	0.2670
TUE	0.3084	0.3605	0.2546	0.2617	0.2519	0.3016	0.3105	0.2705
WED	0.2937	0.3411	0.2397	0.2345	0.2455	0.2871	0.3117	0.2811
THU	0.2935	0.3245	0.2342	0.2386	0.2309	0.2754	0.3361	0.3187
FRI	0.4657	0.8145	0.2400	0.2495	0.2792	0.3125	0.3725	0.3230
AVG.	0.3299	0.4419	0.2382	0.2465	0.2499	0.2903	0.3280	0.2921

Table 4
Intraday volatility converted from per minute to hourly – 2013 (in %)

Day	Hour							
	All-day	9:15 – 10:00	10:00 – 11:00	11:00 – 12:00	12:00 – 13:00	13:00 – 14:00	14:00 – 15:00	15:00 – 15:30
MON	0.2977	0.3520	0.2407	0.2279	0.2633	0.2997	0.3404	0.2757
TUE	0.3089	0.3306	0.2605	0.2861	0.2701	0.3099	0.3408	0.2946
WED	0.3198	0.3453	0.2738	0.2693	0.2661	0.3288	0.3670	0.3238
THU	0.3319	0.3661	0.2591	0.2670	0.2829	0.3407	0.3805	0.3305
FRI	0.3368	0.3869	0.2713	0.2977	0.2901	0.3312	0.3769	0.3136
AVG.	0.3190	0.3562	0.2611	0.2696	0.2745	0.3221	0.3611	0.3077

Table 5
Intraday volatility converted from per minute to hourly – 2014 (in %)

Day	Hour							
	All-day	9:15 – 10:00	10:00 – 11:00	11:00 – 12:00	12:00 – 13:00	13:00 – 14:00	14:00 – 15:00	15:00 – 15:30
MON	0.2420	0.3100	0.2061	0.1812	0.1929	0.2223	0.2756	0.2383
TUE	0.2664	0.3217	0.2134	0.2260	0.2124	0.2464	0.3100	0.2404
WED	0.2386	0.2851	0.2037	0.1805	0.2003	0.2228	0.2804	0.2375
THU	0.2625	0.3140	0.2196	0.1972	0.1944	0.2560	0.3026	0.2802
FRI	0.2907	0.3752	0.2347	0.2260	0.2308	0.2948	0.3300	0.2785
AVG.	0.2600	0.3212	0.2155	0.2022	0.2062	0.2485	0.2997	0.2550

Table 6
Intraday volatility converted from per minute to hourly – 2015 (in %)

Day	Hour							
	All-day	9:15 – 10:00	10:00 – 11:00	11:00 – 12:00	12:00 – 13:00	13:00 – 14:00	14:00 – 15:00	15:00 – 15:30
MON	0.2954	0.3864	0.2529	0.2193	0.2469	0.2759	0.3392	0.2789
TUE	0.3305	0.3716	0.2447	0.2961	0.2781	0.3088	0.3816	0.3089
WED	0.3127	0.3604	0.2500	0.2439	0.2577	0.3078	0.3505	0.2951
THU	0.3083	0.3260	0.2417	0.2133	0.2299	0.3008	0.3440	0.3350
FRI	0.3289	0.3773	0.2556	0.2437	0.2676	0.3007	0.3552	0.3008
AVG.	0.3151	0.3644	0.2490	0.2432	0.2560	0.2988	0.3541	0.3038

Table 7
Intraday volatility converted from per minute to hourly – 2016 (in %)

Day	Hour							
	All-day	9:15 – 10:00	10:00 – 11:00	11:00 – 12:00	12:00 – 13:00	13:00 – 14:00	14:00 – 15:00	15:00 – 15:30
MON	0.2700	0.3244	0.2089	0.2140	0.2515	0.2837	0.2872	0.2326
TUE	0.2675	0.3120	0.2124	0.2269	0.2448	0.2567	0.3048	0.2422
WED	0.2822	0.3448	0.2310	0.2229	0.2346	0.2872	0.3178	0.2461
THU	0.2780	0.3086	0.2122	0.2025	0.2541	0.2817	0.3211	0.2862
FRI	0.2879	0.3694	0.2580	0.2203	0.2430	0.2959	0.3152	0.2475
AVG.	0.2771	0.3318	0.2245	0.2173	0.2456	0.2811	0.3092	0.2509

Table 8
Intraday volatility converted from per minute to hourly – 2017 (in %)

Day	Hour							
	All-day	9:15 – 10:00	10:00 – 11:00	11:00 – 12:00	12:00 – 13:00	13:00 – 14:00	14:00 – 15:00	15:00 – 15:30
MON	0.1805	0.2629	0.1648	0.1398	0.1451	0.2062	0.1808	0.1597
TUE	0.1773	0.2354	0.1662	0.1354	0.1357	0.2179	0.1906	0.1584
WED	0.2095	0.2408	0.1619	0.1533	0.1607	0.2123	0.2391	0.1909
THU	0.1854	0.2161	0.1501	0.1456	0.1602	0.2140	0.2122	0.2129
FRI	0.1859	0.2361	0.1565	0.1372	0.1501	0.2257	0.2119	0.1866
AVG.	0.1877	0.2383	0.1599	0.1422	0.1504	0.2152	0.2069	0.1817

Table 9
Intraday volatility converted from per minute to hourly – Jan. to Aug. 2018 (in %)

Day	Hour							
	All-day	9:15 – 10:00	10:00 – 11:00	11:00 – 12:00	12:00 – 13:00	13:00 – 14:00	14:00 – 15:00	15:00 – 15:30
MON	0.1899	0.2486	0.19258	0.1444	0.1562	0.1824	0.2091	0.1959
TUE	0.2154	0.2620	0.20297	0.1645	0.1768	0.2087	0.2494	0.2116
WED	0.2140	0.2479	0.19203	0.1630	0.1827	0.2105	0.2527	0.2326
THU	0.2154	0.2256	0.17473	0.1572	0.1855	0.2213	0.2541	0.2352
FRI	0.2114	0.2574	0.19940	0.1637	0.1824	0.2011	0.2413	0.2103
AVG.	0.2092	0.2483	0.19234	0.1585	0.1767	0.2048	0.2413	0.2171

As shown in the tables above, intraday hourly volatility decreased steadily from 2011 to 2014 before increasing slightly in 2015. Volatility then decreased in 2016 and 2017 before increasing again in 2018. This increase in volatility in 2018 can be attributed to several national and international macroeconomic, financial and political factors such as rising US-China trade war concerns, growing crude oil prices and current account deficit, depreciation of the rupee against the dollar, tightening interest rates worldwide, the introduction of long-term capital gains (LTCG) tax in the Indian Union Budget 2018 and the upcoming Indian General Elections in 2019.

As can be seen from the tables above, there has been a drop in the average hourly volatility from 0.426% in 2011 to 0.209% in 2018 – a drop of 50.857% over the same period. As stated earlier and found in other studies (Agarwal, Inclan, & Leal, 1999; Bekaert & Harvey, 1997; Santis & Imrohoroglu, 1997), more developed economies tend to display lower stock market volatility. Therefore, part of the aforementioned drop in Nifty 50 volatility can be attributed to increasing development in the Indian economy.

However, the Cboe Volatility Index (VIX) which tracks the volatility of the S&P500 index had an average price of US$24.203 in 2011 which reduced to an average of US$15.414 in 2018 (till Aug.) – signifying a drop of 36.314% – over the same period (Yahoo Finance, 2018). Moreover, the Cboe EFA ETF Volatility Index (VXEFA) – an index measuring the expected volatility of the iShares MSCI EAFE Index Fund (EFA) which offers exposure to developed markets in Europe, Australia, Asia among others – had an average price of US$31.306 in 2011 which fell to an average of US$13.142 in 2018 (till Aug.) – denoting a decline of 58.022% (Cboe Options Exchange, 2018). Therefore, the drop of volatility in the Nifty 50 from 2011 to 2018 can also be explained as a global phenomenon. Our inability in distinguishing the cause of the drop leads us to fail in proving our hypothesis that development in the Indian economy led to lower stock market volatility.

4. Concluding Remarks

In this paper, we find that (i) intraday volatility of stock returns in the NSE follows the expected U-shaped pattern; (ii) 11:00 to 12:00 is the time period exhibiting the least volatility; (iii) hourly intraday volatility of the Nifty 50 has been decreasing steadily since 2011; and (iv)

there is insufficient evidence to show that development in the Indian economy has led to lower volatility in its stock market.

These empirical results give evidence supporting the presence of an U-shaped pattern of intraday volatility in the NSE. However, further research is needed to discern the effect that the development of the Indian economy has had on volatility in its stock market in light of a similar reduction in volatility worldwide during the same period (Jan 1, 2011 to Aug 31, 2018).

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