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Variance Ratio Tests of the Random Walk Hypothesis for Indian Stock Index Futures: Evidence from High Frequency Data

By- Priyanka Singh and Brajesh Kumar[1]

INTRODUCTION

The main aim of the paper is to test the random walk hypothesis for Indian stock index (NIFTY) futures using variance ratio tests. This work is done using high frequency data at levels of five minute, hourly and daily prices. Any randomness check at daily level is not very informative as markets are generally efficient at daily frequency level. Hence intraday analysis would be more informative to investigate any departure from randomness. Analysis at high frequency gives useful insights about the behavior of prices as any news arrive and whether the investors of the market process the information efficiently.

The efficient market hypothesis says that any efficient price series should follow random walk. The investigation of randomness is the weak form of market efficiency. However, there can be two types of deviations in case of inefficiency: mean reversion and persistence. In mean reversion, any information shock to the price series is temporary and the effect dies down quickly. Mean reversion is often attributed to overreaction by investors, which leads to temporary deviations from long term mean and is subsequently corrected leading to presence of mean reversion. Persistence, which is a long memory in prices due to prolonged effect of any shock, is attributed to slow reaction by investors to the current information vis-à-vis prior information. Persistence may also be due to infrequent trading, degrees of substitution among assets and liquidity constraints. Both mean reversion and persistence advocate the presence of a predictable component in the prices. However, this predictable component may not lead to profitable trading strategies due to transaction costs involved.

The issues of randomness/mean reversion in stocks, stock futures, interest rate, exchange rate, commodity prices, and commodity futures are extensively studied in the past. *Poterba and Summers (1988)* tested 20 stocks for randomness in the US and found evidence of mean reversion/ negative correlation. *Lo and MacKinlay (1988)* used Variance Ratio tests to investigate the random walk hypothesis for many indices and found mixed results. *Low and Muthuswamy (1996)* examined market efficiency by using Variance Ratio tests for five minute returns and found evidence of mean reversion. *Barkoulas et. al (1997)* applied Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test of unit root on 20 commodities and one composite index. A random walk is rejected for copper, jute and tea by PP test, whereas the stationary hypothesis (KPSS test) was rejected for all commodities except copper, jute, wool and zinc. Pindyck *and Rubinfeld (1991)* used the 100 years data and reject the random walk in the spot prices of copper and crude oil. *Wahab (1995)* used ADF test and did not reject random walk for gold and silver futures. Irwin et al. (1996) examined the mean-reversion in corn, soybean, wheat, live hog and live cattle futures prices using Monte Carlo simulation techniques. They found mean-reversion in commodities futures prices, when asymptotic regression was used. However, Monte Carlo simulation did not support the existence of mean-reversion in the commodities prices. *Fraser and Andrew (1998)* studied the behavior of asset prices in terms of departure from randomness and market efficiency. They used variance ratio test to investigate the departure from randomness in form of mean-reversion (short memory) and persistence (long memory). It was found that aluminum, Brent, copper and gas oil prices were not random. They had mean-reversion or persistence characteristics. *Wang and Ke (2005)* studied Chinese wheat and soybean futures market and tested the randomness of the series by ADF test. It was found that both wheat and soybean futures prices are random. *Andersson (2007)* used LM variance ratio test, PP test, KPSS test and hedge test to investigate the randomness in the 280 commodities price series. A random walk is rejected for around 40% of the price series while LM variance ratio test was used. Unit root hypothesis was rejected for some 10% price series by PP test. However, KPSS, which has stationarity as null hypothesis, mean-reversion is accepted for even fewer series. *Thomas and Patnaik (2002)* tests market efficiency of Indian stocks using Variance Ratio tests at five minute return. At this frequency stocks showed mean reversion.

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METHODOLOGY

Unit root tests are used to test for stationarity. If the series is stationary then the unit root will be absent and vice versa. Stationarity implies temporary effect of any information while unit root presence will reflect permanent effect of the information/shock. Several tests have been developed for unit root tests. In this study, we use Augmented Dickey Fuller (ADF) test for testing unit roots. The null hypothesis for ADF test is presence of a unit root.

Variance ratio test is based on the fact that if a time series follows a RW, in a finite sample the increments in the variance are linear in the observation interval. That is, the variance of difference data should be proportional to the sample interval. Defining yt is the first difference of the log of prices and can be modeled as stochastic process having drift as follows,

$$y_t = \mu + y_{t-1} + \varepsilon_t$$

where, μ is the drift parameter, expected value of error is zero and $E(\varepsilon_t \varepsilon_{t-1}) = 0$. The restriction on the errors implies that the variance of the error will grow linearly with the time step. Following *Lo and MacKinlay (1988)* and *Chow and Denning (1993)*, the variance of (yt-yt-1) is 1/n times the variance of (yt-yt-n). In another words,

$$\frac{(1/n)\,VAR(y_{t+n} - y_t)}{VAR(y_{t+1} - y_t)} = 1$$ will hold asymptotically even with possible heteroscadastic increments. Furthermore, given a finite number of price movements represented by nq+1 consecutive yt s, the Lo-MacKinlay variance ratio estimate is calculated as

$$\bar{M}(q) = \frac{\bar{\sigma}^2(q)}{\bar{\sigma}^2(1)}$$

where,

$$\bar{\sigma}^2(q) = \frac{1}{q(nq - q + 1)\left(1 - 1/n\right)} \sum_{i=q}^{nq} \left(y_i - y_{i-q} - q\hat{\mu} \right)^2$$

$$\bar{\sigma}^2(1) = \frac{1}{(nq-1)} \sum_{i=1}^{nq} \left(y_i - y_{i-1} - \hat{\mu} \right)^2$$

$$\hat{\mu} = \frac{1}{nq} \sum_{i=1}^{nq} (y_i - y_{i-1})$$

The Z* test statistics derived by Lo and MacKinlay is as follows;

$$Z^*(q) = M_r(q) \left[V(q) \right]^{-1/2} \approx N(0,1)$$

$$V(q) = \sum_{j=1}^{q-1} \left(\frac{2(q-j)}{q} \right)^2 \hat{\delta}(j)$$

$$\hat{\delta}(j) = \left((nq) \sum_{i=j+1}^{nq} \left(y_i - y_{i-1} - \hat{\mu} \right)^2 \left(y_{i-j} - y_{i-j-1} - \hat{\mu} \right)^2 \right) \times \left(\sum_{i=1}^{nq} \left[\left(y_i - y_{i-1} - \hat{\mu} \right)^2 \right]_2 \right)^{-1}$$

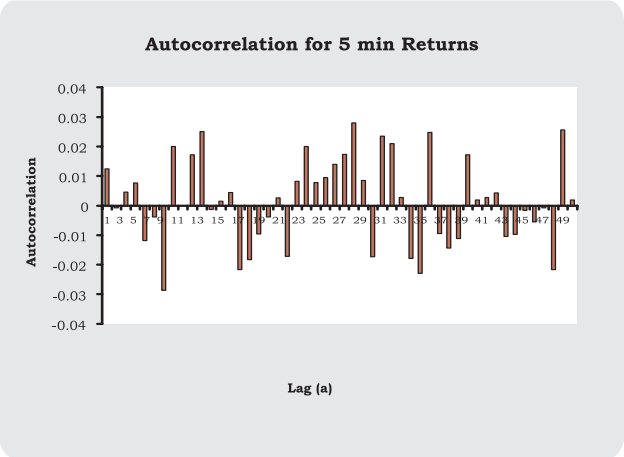
The random walk hypothesis requires that the variance ratio for all the chosen aggregation intervals, q, be equal to one. If variance ratio is less than one than the series is said to be mean reverting and if variance ratio is greater than one than the series is said to be persistent. Variance ratio tests for return can be applied directly unlike to volatility where we need to deal with intraday periodicity.

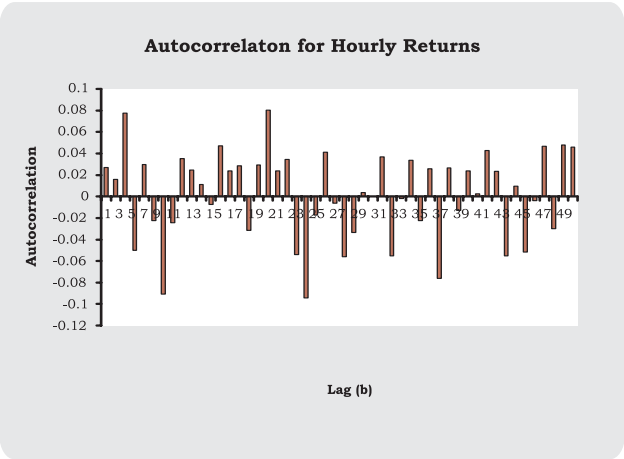
DATA AND ITS DESCRIPTIVE STATISTICS

The data used in this study is Nifty index futures (nearest maturity futures) comprising of 50 large capitalization stocks. The data is taken from January, 2008 through October, 2008, which is the latest data provided by NSE in the form of NSE data CDs. The first ten minute data after opening is deleted due to the staleness of the data *(Stoll and Whaley, 1990)*. Different frequencies are chosen for comparison within intraday. The basic statistics for prices are given in table 1.

It can be seen that basic statistics for prices are not very different across various frequencies but they are different in return across various frequencies (table 2). The kurtosis decreases as we move from five minute returns to daily returns. Five minute returns distribution is most away from a normal distribution. As expected the mean return and standard deviation increases from five minute to hourly to daily returns. Table 3 gives the autocorrelation function for five min, hourly and daily returns. Up to lag twenty, autocorrelation is higher for five minute returns and hourly returns; thereafter autocorrelation for daily returns is higher. Initial autocorrelation for daily is negative implying price correction rather than persistence for some time whereas

for five minute return and hourly returns it is positive implying delayed assimilation of information. Autocorrelation is alternatively negative and positive for all the returns. This implies price correction or information gets adjusted for any overreaction in this series (Figure 1).





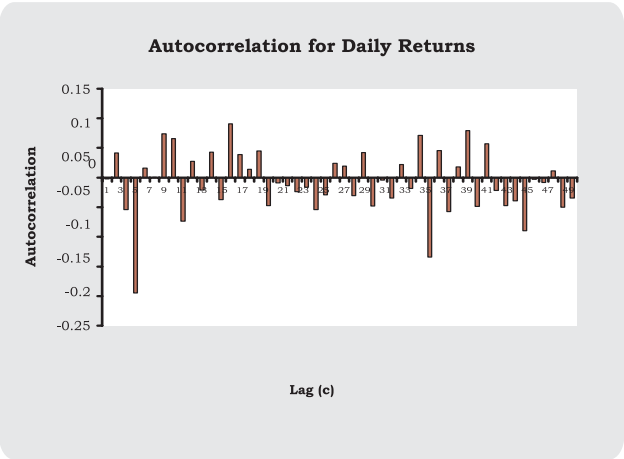


Table 1: Basic Statistics (prices)

	5 minute	Hourly	Daily
Mean	4638.884	4646.655	4614.416
Median	4618.265	4625.170	4608.200
Maximum	6334.140	6334.140	6288.250
Minimum	2520.578	2619.867	2517.500
Standard Deviation	662.002	662.353	715.578
Kurtosis	0.916	0.894	0.895
Skewness	0.005	0.020	-0.204

Table 2: Basic Statistics (return %)

	5 minute	Hourly	Daily
Mean	-0.007	-0.077	-0.368
Median	0.002	-0.021	-0.253
Maximum	5.796	5.631	7.404
Minimum	-7.897	-8.825	-13.677
Standard Deviation	0.342	1.168	2.910
Kurtosis	84.132	7.308	2.260
Skewness	-2.579	-0.786	-0.418

Table 3: Autocorrelation of Return at diff Frequencies

	Five minute	Hourly	Daily
q=1	0.0124	0.0198	-0.0021
q=5	-0.01182	0.0218	0.016
q=10	0.01721	0.018	0.0276
q=15	-0.02162	0.0211	0.0386
q=20	-0.01714	0.0254	-0.0138
q=25	0.014	-0.0047	0.0242
q=30	0.02351	0.0269	-0.0043
q=35	0.02478	0.0188	-0.1342
q=40	0.00184	0.0019	-0.049
q=45	-0.0016	-0.0379	-0.0895
q=50	0.00191	0.0337	-0.0347

RESULTS

Unit root tests using ADF is conducted at lag length ten for price series. It can be seen from table 4 that all the price series, five minute, hourly and daily, the unit root is not

rejected. All the return series come out to be stationary (results not reported here). For further insight about the behavior: randomness, mean reversion and persistence, adjusted multiple variance ratio tests was applied.

Variance ratio test results of five minute, hourly and daily prices are presented in table 5. It is found that prices at five minute, hourly and daily frequencies are random (statistically). The tests is carried out and reported till lag 500. This result is in contrast to the findings of Thomas and Patnaik (2002) who found evidence of mean reversion in stocks using VR tests. It is important to note here that even though statistically all are random, five minute return show tendency towards persistence (VR> 1) at all lags. Hourly returns show persistence (VR> 1) till lag 9 and later tendency towards mean reversion (VR< 1). On the other hand, daily returns show inclination always towards mean reversion (VR < 1). This is expected as information procession is slow at high frequency than at low frequency prices.

Table 4: Unit Root Tests (tau)

	Five minute price	Hourly price	Daily price
Single Mean	-1.6044	-2.1985	-2.7171
Trend	-9.1075	-12.213	-21.958

** significant at 1 percent level

Table 5: Variance Ratio Tests of Nifty Futures at Various Frequencies

	Five minute	Hourly	Daily
q=5	1.0487	1.1534	0.96632
q=10	1.0315	1.15	0.88512
q=15	1.0543	1.1614	0.85363
q=20	1.0477	1.206	0.8865
q=25	1.0487	1.22	0.87533
q=30	1.0778	1.1891	0.84031
q=40	1.1361	1.1406	0.78858
q=50	1.163	1.0821	0.75506
q=100	1.1789	0.95334	0.75276
q=500	1.1357	0.93437	

* significant at 5 percent level

CONCLUSIONS

It is found that all the prices series, five minute, hourly and daily, are random at five percent level (statistically). The result is consistent in unit root and variance ratio both. However, the autocorrelation and variance ratio show mean reversion tendency, though insignificant, for five minute prices, which is not the case with hourly and daily prices. In all, it can be said that Indian market is weak form efficient.

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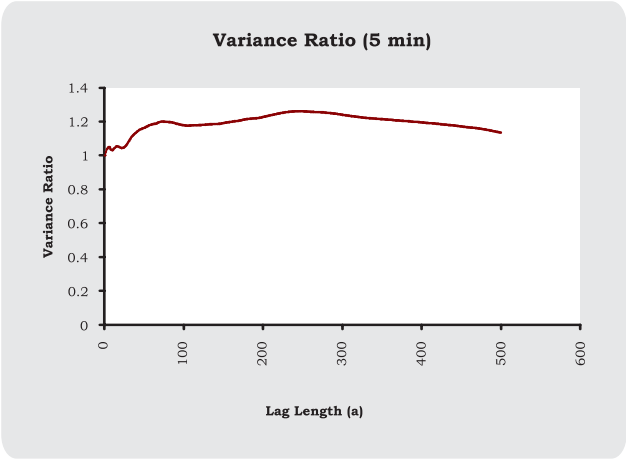
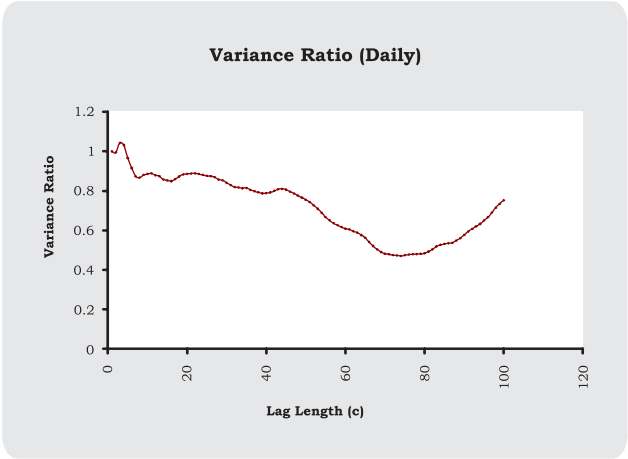

Variance Ratio (5 min)
Variance Ratio
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
600
Lag Length (a)


Variance Ratio (Daily)
Variance Ratio
1.2
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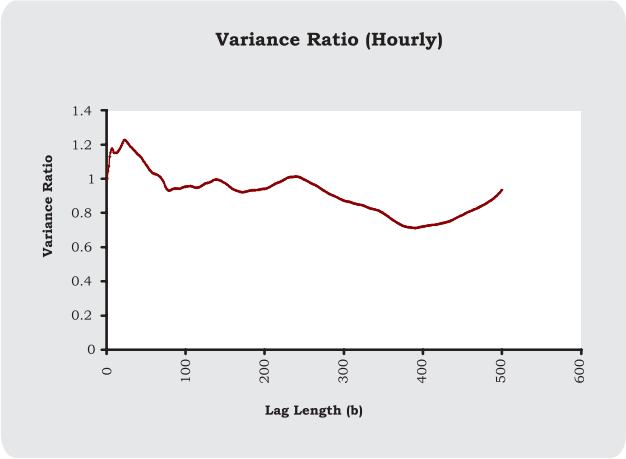
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
Lag Length (c)


Variance Ratio (Hourly)
Variance Ratio
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
600
Lag Length (b)