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The Impact of the Us Equity Market Movements on Overnight Returns in the Indian Stock Market: The Moderating Role of Market Volatility

Advait Rohatgi

Abstract:
This paper studies the relationship between returns in the US equity market and opening gaps in the subsequent Indian Nifty 50. The relationship is studied while also considering whether the relationship varies during periods of high expected US equity volatility. Daily closing and opening prices for the S&P 500 and Nifty 50 are used in conjunction with closing values for the Cboe Volatility Index (VIX). A sample of 239 eligible days is created from 2025 data. The relationship is then examined using correlation, simple linear regression, directional agreement, and average opening gap. For the overall sample, there is a positive correlation (0.386) and R^2 of 0.149. This means that the fitted linear relationship explains roughly 14.9% of the variation in the opening gaps for the Indian Nifty 50. For days with high VIX values, there is a higher correlation (0.433) and R^2 of 0.188 compared to the other days, which have values of 0.288 and 0.083, respectively. The level of directional agreement, however, is similar at 63.9% and 63.5% for the high and the other days, respectively. This analysis suggests a positive relationship between the returns in the US equity market and the subsequent opening gaps in Indian equities. The relationship appears to be stronger during high volatility days. A sensitivity check shows that part of the strength of the fitted relationship comes from one unusually large observation: the Indian trading day of 7 April 2025, matched to the US session of 4 April 2025. However, these results are merely descriptive and do not imply causality, statistical significance, or the ability to forecast out of sample.

1. Introduction:

International financial markets are all interconnected. However, some financial markets do not trade at all times. For example, the US market generally finishes trading after the Indian market has closed and before the Indian market opens again. This allows research to be conducted into whether there is a relationship between the US market and the opening of the Indian market.

The relationship studied is economically important because there may be some shared information that is acted upon by investors in different countries. For example, changes in expectations about inflation, interest rates, corporate earnings, economic expansion, geopolitical risk, or growth may affect valuation in different markets. A positive or negative session in the US equity market can contain some information that affects valuation in Indian markets and companies. This could then result in some adjustment in the price of Indian equities between the close of the previous day and the opening of the subsequent day.

A relationship, however, is not expected. The S&P 500 is composed of US large-cap companies, while the Nifty 50 is composed of large listed companies in India. The two indices have different exposure to the global economy, exposure to different sectors, and different currencies. Domestic information about

India, such as changes in the Indian rupee, commodity prices, domestic company information, domestic government policies, and domestic news, may also affect the opening price of Indian equities without necessarily being related to a session in the US market. Furthermore, the size of the change in a US market session may not be directly related to the size of a change in the subsequent Indian opening.

This analysis will study the relationship using two daily measures. The first is the return for the US cash session for the S&P 500. The second is the opening gap of Indian equities relative to the close of the previous Indian trading day. The opening gap is used as a proxy for the adjustment in price between the closes and opens of Indian sessions.

This analysis will also examine whether the relationship between the US market and the subsequent opening in Indian equities differs during periods of high expected US equity volatility. The VIX is used to determine which days are in the high-volatility group and which days are in the other-day group. The VIX is described by Cboe as a market-based estimate of the expected volatility of the S&P 500 over the next 30 days using the option prices on the S&P 500 index. (Cboe, n.d.) Therefore, the VIX is used as a proxy for expected volatility in US equity markets but is not a direct measure of volatility in the Indian equity markets.

There are two hypotheses tested for this study.

Hypothesis 1 (H1): Positive returns in the S&P 500 session tend to be related to positive opening gaps in the subsequent Nifty 50, while negative returns in the S&P 500 session tend to be related to negative opening gaps in the subsequent Nifty 50.

Hypothesis 2 (H2): The relationship between positive returns in the S&P 500 session and positive opening gaps in the subsequent Nifty 50 is stronger during periods of high expected US equity volatility.

The word "explain" in the research question refers to the relationship between the variables as well as the relationship found by the fitted linear regression model. It does not imply that a certain proportion of Indian opening gaps are explained by US returns. The term overnight returns refers to the opening gap used in this analysis rather than the actual return earned by an investor after transaction costs and execution costs.

The data used in this analysis are from 2025, and calculations are performed using a spreadsheet. First, the full sample is examined, and then an examination of the high-volatility and other-day samples is performed. Finally, the results of the analysis are discussed with regard to limitations, implications, and how well the results support the hypotheses.

2. Conceptual Background and Analytical Framework:

Prices in financial markets contain information about the expected future performance of markets, economic conditions, discount rates, and risk. When new information becomes available about any of these factors, investors may revise the prices they are willing to pay for financial assets. This means that some information that is relevant to more than one country can be reflected in more than one market.

International financial spillovers can provide context for the types of cross-market relationships that can be studied. For example, Diebold and Yilmaz (2012) have developed measures for directional volatility spillovers between financial markets. Their study demonstrates the importance of not confusing the existence of volatility spillovers with the magnitude of those spillovers. However, this framework is more advanced than the correlation and simple regression analysis performed in this study. This study should therefore be considered to be a descriptive study of a specific relationship between international markets rather than a study of volatility spillovers.

Another limitation of this analysis is that daily financial market prices are used. The S&P 500 and the Nifty 50 are composed of different companies with different economic exposures. A positive relationship could be due to some shared information, but it could also be due to differences in the markets or information that arrives in India that is not related to information in the US market.

2.1 Why volatility may matter:

It is possible that the relationship between the US market and the subsequent opening in the Indian market may vary during periods of high volatility in the US market. During high volatility, investors may react more to shared information, which could result in more synchronized price responses between the US and Indian markets. This justifies the study of whether the fitted relationship varies during periods of high volatility.

Another reason that volatility may matter is that high volatility may lead to more uncertainty and more diverse investor responses. During high volatility, it is not necessarily expected that markets will react more synchronously. Instead, high volatility may lead to larger individual responses that are more difficult to predict.

The VIX is an appropriate volatility measure to be used as a classifier because it is a measure of expected volatility in US equity markets. However, it is not a direct measure of volatility in the Indian equity markets. This study instead examines whether the US VIX classification is related to a difference in the observed US-India relationship rather than attempting to isolate the impact of volatility in India.

Another methodological reference is provided by Robert Engle's work on dynamic conditional correlation. In Engle (2002), a framework for modeling time-varying correlations is provided. This analysis does, however, not estimate a dynamic conditional correlation model. Instead, correlation and simple linear regression are used to examine two groups. A difference in correlations between two groups is not the same as estimating a time-varying correlation.

2.2 Analytical Framework:

The four main measures used in this study are:

Correlation: Determines the strength and direction of the linear relationship between the returns in the US market and the subsequent opening gaps in the Indian market.

Regression slope: Determines the change in the opening gap of Indian equities associated with a one-percentage-point change in the return in the US market.

R^2: Measures the percentage of the observed variation in the opening gaps of the Indian equities that are explained by the fitted linear model in the sample.

Directional agreement: Determines the percentage of observations in which the US market return and the subsequent Indian opening have the same non-zero sign.

These measures address slightly different questions. Correlation and R^2 are mathematically related in a simple linear regression with an intercept. A larger slope does not necessarily imply a larger correlation or a better-fitting model. A larger R^2 does not imply causation or out-of-sample forecasting ability.

The analytical framework therefore looks to see if there is support for each hypothesis without assuming a specific strength of the relationship or a specific effect of high volatility on the relationship.

3. Data and Methodology:

3.1 Data sources and study period:

Daily data is used for the 2025 calendar year. In addition, an additional data point is used as required to calculate the first Indian opening.

There are three main data series used in this study:

Nifty 50: Daily opening and closing prices for the Nifty 50 are taken from historical NSE Indices data.

S&P 500: Daily opening and closing prices for the S&P 500 are taken from the historical prices found in the project workbook. In the source section of the workbook, the data is attributed to The Wall Street Journal.

VIX: The closing values of the VIX are taken from the historical data provided in the project workbook and attributed to the Wall Street Journal historical prices. In addition, a subset of data points is cross-checked against the VIXCLS data published by FRED, which is derived from the Cboe-sourced VIX.

The project workbook contains all of the original data points used in this study, the dates of those data points, the matched sample used in this study, excluded data points, calculation sheets, summary statistics, and a ten-observation manual check sheet.

3.2 Variable definitions:

The dependent variable is the opening gap for the Indian Nifty 50. This opening gap is the percentage change between the current Indian opening and the close of the previous Indian trading day.

$$G_t = \left(\frac{\text{Nifty 50 Open}_t}{\text{Previous Nifty 50 Close}_t} - 1 \right) \times 100$$

The independent variable is the return in the US cash session for the S&P 500. The return is defined as the percentage change between the close and the open for the cash session in the US market.

$$R_t = \left(\frac{\text{S\&P 500 Close}_t}{\text{S\&P 500 Open}_t} - 1 \right) \times 100$$

G_t denotes the Nifty 50 opening gap and R_t expresses S&P 500's returns; both are expressed as percentages.

This means that the slope of the fitted linear regression can be interpreted as the estimated change in the opening gap of Indian equities, in percentage points, associated with a one-percentage-point change in the return in the US cash session for the S&P 500.

The opening gap is not a complete measure of the return earned by an investor. It does not include dividends, transaction costs, slippage, or the exact prices at which an investor could trade a security.

Another limitation is that the return in the US cash session only includes information from that session. This return does not represent all information or price movements in the full Indian close-to-open session.

The results of this analysis should therefore be interpreted as a relationship with returns in the US cash session rather than a complete analysis of all repricing in the US market overnight.

3.3 Matching US and Indian sessions:

Matching the US and Indian market sessions is important to the analysis. A simple matching using the calendar date for the US and Indian sessions could result in matching the incorrect US session to the Indian opening, especially during weekends and holidays for the exchange.

The matching used in this analysis is based on the closing date in the Indian market, the opening date in the Indian market, and the available US market sessions in the time period between the closing and opening of the Indian session. If exactly one completed US session occurs in the time period between the closing and opening of the Indian session, then that session is used in the analysis. For eleven time periods, two US sessions occurred during an Indian market closing. A revised matching rule used in the project workbook was followed for these observations, and the most recent US session before the opening of the Indian session was used. The earlier sessions are recorded in the matching sheet.

Table 1. Observation matching and sample selection

Observations before exclusions	249
Excluded observations	10
Final usable sample	239

Ten observations were excluded from this study because no completed US session occurred in the time between the closing and opening of the Indian session. These exclusions are recorded individually in the project workbook. A total of 239 eligible observations are used in the analysis.

This matching procedure allows eligible observations to be matched to a relevant completed US session without using calendar-date matching. However, matching the most recent session when two sessions occurred is an arbitrary choice and does not mean that the selected session represents all of the information used by the Indian market during the longer time period.

A ten-observation manual check is done in the workbook. This allows for a spot check on the calculations and the matching procedure. However, this manual check is not equivalent to fully independent checking of all observations using official exchange calendars and time-zone-aware timestamps. This limitation is also considered in the results.

3.4 Volatility classification:

Each eligible observation is classified based on the closing value of the VIX from the selected US session. High VIX is defined as a closing value that is at or above the 75th percentile of the eligible matched VIX

values.

The cutoff value in the workbook is 19.83. Any observations with a closing value of 19.83 or above are classified as high VIX, and any observations with a closing value below 19.83 are classified as other days. This creates two groups:

- High VIX: 61 observations.
- Other days: 178 observations.

This cutoff is a relative cutoff for the sample of eligible observations used in this analysis. It does not imply that all observations below the cutoff value represent calm conditions in the US market. There is still a possibility of significant volatility present in the other-day group.

3.5 Statistical analysis:

The same set of analyses is conducted for the full sample and for each volatility group.

The correlation is computed between the US return and the subsequent Indian opening gap. A positive correlation indicates that there is a positive linear relationship between the two variables. That is, if the US return is high, then the subsequent Indian opening is also likely to be high.

The simple linear regression is specified as:

$$G_t = \alpha + \beta R_t + \varepsilon_t$$

Here, G_t is the Nifty 50 opening gap, R_t is the S&P 500 session return, α is the intercept, β is the regression slope, and ε_t is the error term.

The R^2 statistic is computed for the fitted regression model. In a simple linear regression with an intercept, the R^2 equals the square of the correlation between the independent and dependent variables. R^2 is therefore reported along with correlation for completeness. However, correlation and R^2 should not be treated as independent evidence.

Directional agreement is computed as the percentage of observations in which the US market return and the subsequent Indian opening have the same non-zero sign. 239 observations are used in the analysis, and there are no zero-return observations in the analysis. The counts of same sign matches are consistent with the directional agreement percentages reported for the analysis. However, the classification rule should also be recorded in the workbook so that any future data updates are performed consistently.

$$\text{Directional Agreement (\%)} = \frac{\text{Same-direction matches}}{\text{Usable observations}} \times 100$$

Directional agreement measures the percentage of useful observations in which the S&P 500 session returns and the respective Nifty 50 opening gaps have the same non-zero sign. A calculated example is displayed below:

152/239 x 100 = 63.6%

Finally, average opening gaps of Indian equities that follow positive returns in the US market and negative returns in the US market are computed for the full sample and for each volatility group. These averages provide additional descriptive information about the direction of the relationship between the two variables.

This analysis is observational and descriptive. A statistical test for differences between the VIX groups is not conducted. Also, the relationship between the two variables is not examined for causality or an out-of-sample forecast period.

4. Full-Sample Results:

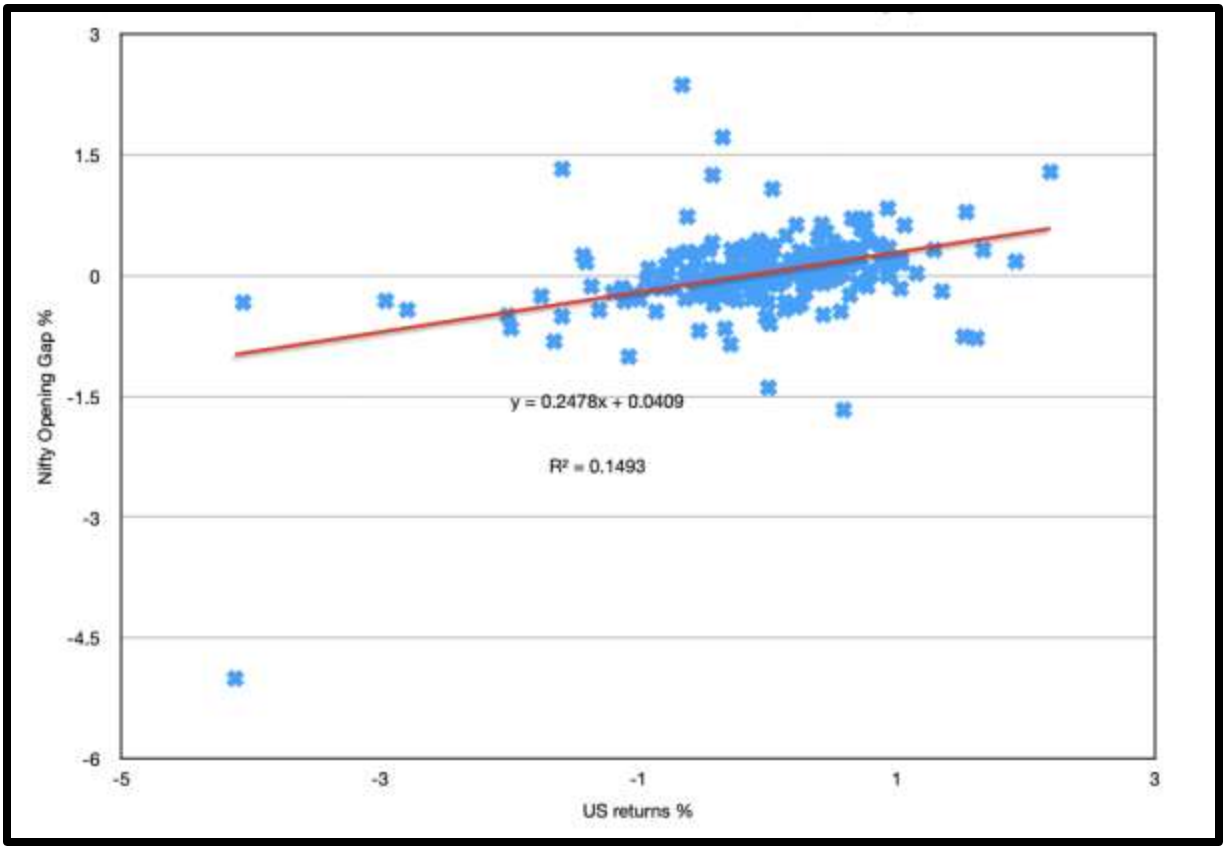
4.1 Correlation and regression:

For the full sample, there are 239 eligible observations. There is a positive correlation between the return in the US cash session for the S&P 500 and the subsequent opening gap in the Indian Nifty 50. The correlation is 0.386. This indicates that there is a positive linear relationship between the two variables. The relationship, however, is not especially strong.

The fitted linear regression is approximately:

$$G_t = 0.0409 + 0.2478 R_t$$

Where 0.0409 is the intercept, 0.2478 is the regression slope, and R_t is the S&P 500 session return.



The slope of 0.2478 indicates that for a one-percentage-point change in the S&P 500 return, there is a corresponding 0.2478-percentage-point increase in the opening gap of the Indian Nifty 50, according to

the above linear model. This is an average fitted relationship across all of the observations rather than an indication that a change in the US market will be proportionally followed by a change in the Indian market. The intercept is approximately 0.0409 percentage points. The intercept is a value in the fitted linear regression model and represents the opening gap of the Indian Nifty 50 when the US session return is zero. It is not interpreted as a market return or a consistent market return.

The R^2 is 0.149. This means that the fitted linear model is able to explain approximately 14.9% of the observed variation in the opening gaps of the Indian Nifty 50 in this sample. The remaining 85.1% of the variation in opening gaps in the Indian Nifty 50 is not explained by this one-variable linear regression. This does not mean that 14.9% of the variation in the opening gaps of the Indian Nifty 50 is caused by changes in the US market. R^2 is a measure of in-sample fit and not causation.

A scatter plot is helpful to determine if the positive relationship is present across the sample or driven by a few unusually large values. The regression results describe the overall linearity in the data but do not suggest that every observation lies on this line.

4.2 Directional agreement and average gaps:

The workbook shows that there is directional agreement of 63.6% between the returns for the US session and the opening gap in India. This is based on 152 instances of the same non-zero sign between the two variables out of a total of 239 observations.

The average opening gap for Nifty 50 following a positive return in the US session is +0.114%. The average opening gap following a negative return in the US session is −0.048%. This difference in the means is consistent with both the positive correlation and the positive slope in the regression.

However, this does not mean that a positive return in the US session will result in a positive opening gap in India and vice versa for a negative return. This describes averages across the sample but does not remove the impact of any other information in the market.

To give some context to the directional agreement rate, the signs of the data can be examined in a two by two contingency table.

From this table, it is clear that positive returns in the US are more likely to be followed by a positive Indian opening gap than a negative opening gap. Similarly, negative returns in the US are more likely to be followed by a negative than a positive opening gap in India. There are 91 instances where both signs are positive and 61 instances where both signs are negative. This results in 152 instances of agreement.

The majority sign benchmark would always predict a positive opening gap in India because 141 of the 239 opening gaps are positive. This would result in an in-sample accuracy of approximately 59.0% compared to the directional agreement of 63.6%. The observed accuracy is therefore about 4.6 percentage points higher than the majority sign benchmark.

This can provide some context to the observed accuracy but is not a formal test of accuracy. The majority sign benchmark is calculated based on the same sample, and whether the difference between the two values is statistically significant or would occur on another sample is not addressed.

4.3 Assessment of Hypothesis 1:

All of the results from the full sample, including the correlation, positive slope, average gaps, and directional agreement, support H1. There appears to be a positive relationship between a positive return in the US session and a positive opening gap in India. Likewise, a negative return in the US session appears to be followed by a negative opening gap in India.

There is some support for a positive relationship, but the strength of this relationship is limited. The R^2 of 0.149 suggests that the return in the US session explains only a relatively small amount of the variation in

the opening gap in India. As such, it is not sufficient to explain most of the variation observed in the India opening gap.

H1 is supported descriptively across the 2025 sample but does not support causality or a trading strategy based on the relationship observed.

5. Volatility-regime results

5.1 Group comparison:

The VIX threshold of 19.83 separates the 239 observations into 61 observations with a high value of VIX and 178 observations with a low value of VIX. The results for each of these two groups are tabulated below.

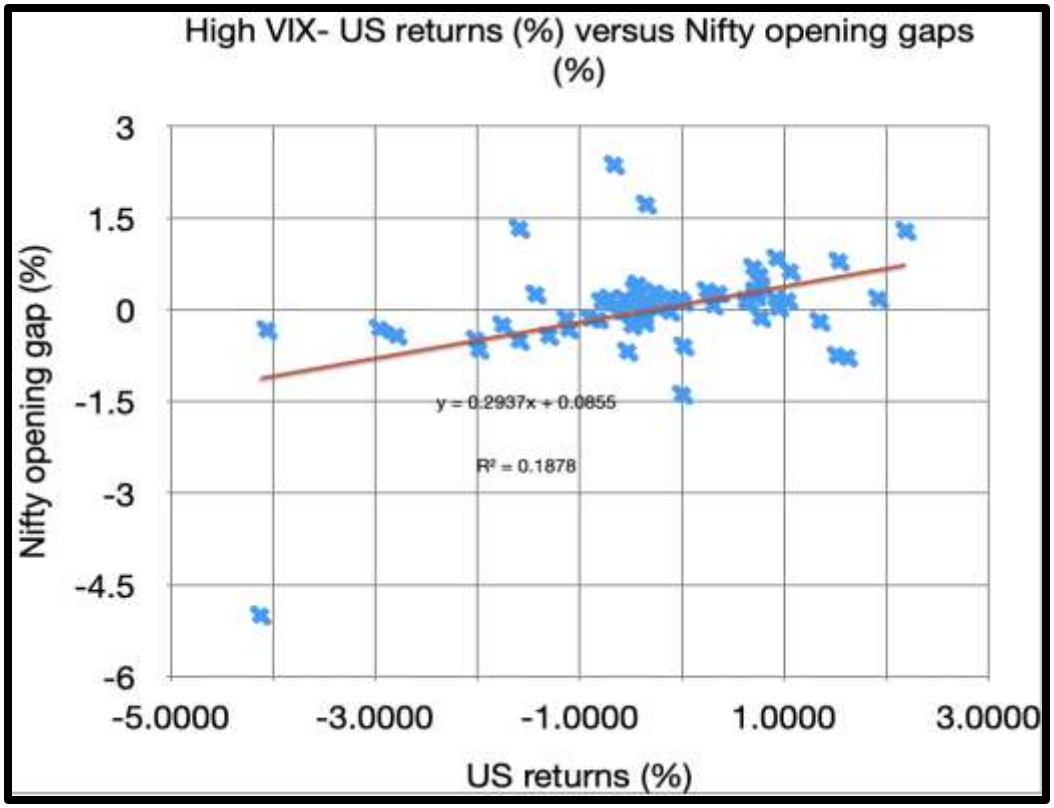
Table 2. Comparison of US-session returns and Nifty 50 opening gaps across volatility regimes. The full sample includes both high and low VIX observations. High VIX is defined as a matched closing VIX value at or above 19.83, which is the 75th percentile cutoff. Contrarily, "Other days" refers to the VIX observations that lie below the cutoff.

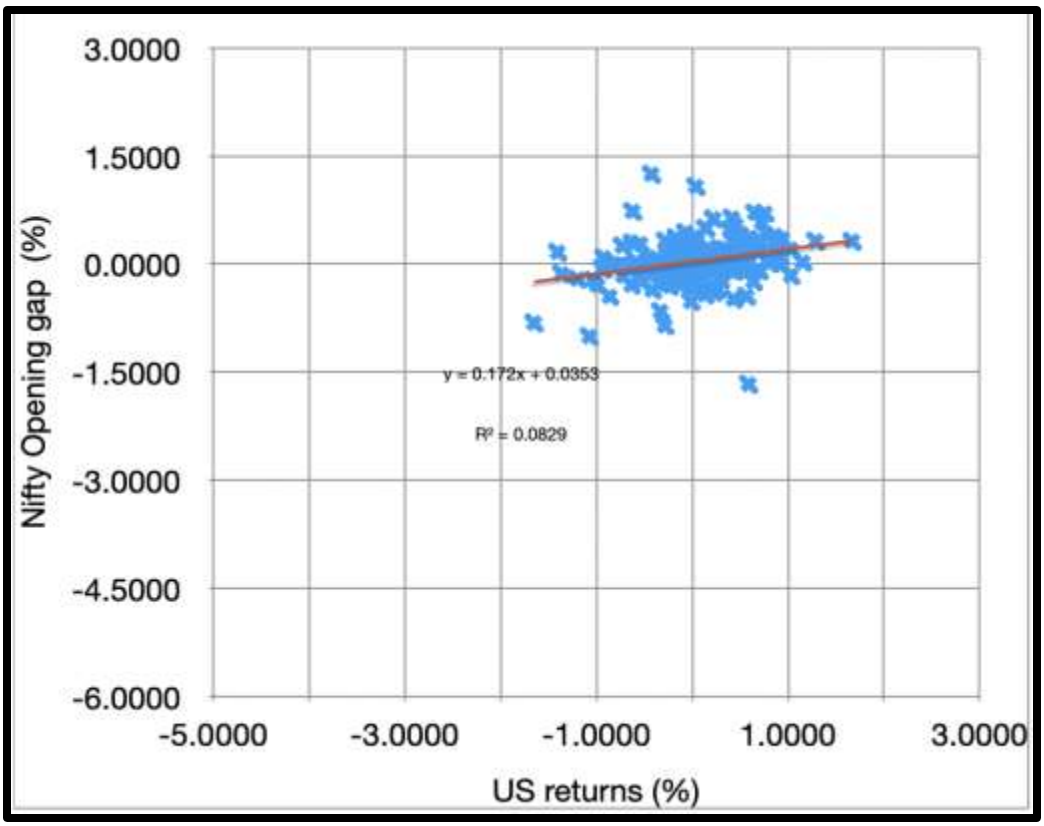
Metric	All eligible days	High VIX	Other days
No. Of Usable observations	239	61	178
Correlation	0.386	0.433	0.288
Slope	0.248	0.294	0.172
R-squared	0.149	0.188	0.083
Direction match (%)	63.6%	63.9%	63.5%
US up-day count	128	26	102
US down-day count	111	35	76
Excluded observations	10	-	-

The correlation for the high-VIX observations is 0.433 compared to 0.288 for observations with a low value ("other days") of VIX. Both of these values are positive, but the correlation is greater in the high-VIX group.

The regression slope for high-VIX observations is also higher at 0.294 compared to 0.172 for observations with a low value of VIX. For the high-VIX observations, for each one-percentage-point increase in the US session return, there is an estimated 0.294-percentage-point increase in the Indian opening gap compared to 0.172 percentage points for the observations with a low value of VIX. This suggests that there is a greater level of fitted sensitivity in the high-VIX group.

The R^2 for the high-VIX observations is 0.188 compared to 0.083 for the low-VIX observations. This suggests that the fitted linear model explains approximately 18.8% of the variation in the opening gaps in the high-VIX observations compared to 8.3% of the variation in the opening gaps in the low-VIX observations. The fit is better for the high-VIX observations, but a large amount of the variation remains unexplained in both groups.





5.2 Return dispersion:

There is also greater dispersion in both variables for the high-VIX observations. The standard deviation

of the US-session returns for the high-VIX observations is approximately 1.300 percentage points compared to 0.545 percentage points for the low-VIX observations. The standard deviation of the Indian opening gaps for the high-VIX observations is approximately 0.881 percentage points compared to 0.325 percentage points for the low-VIX observations.

This suggests that there is greater dispersion in the US-session returns and the opening gaps in India for the high-VIX observations. This is relevant as the groups also differ in their return distributions as well as their fitted slopes and correlations.

The higher correlation and R^2 for the high-VIX observations are not independent results. In a simple linear regression with one independent variable and an intercept, the R^2 value is equal to the squared correlation coefficient. This means that both the correlation and R^2 are describing the same relationship from two different perspectives. The slope value provides a different measure of the fitted relationship.

Greater dispersion does not necessarily explain the difference in the two groups or the stronger relationship during high-VIX regimes. However, it does provide some caution regarding the interpretation of the group comparison as a causal effect of volatility. An analysis of the sensitivity of the results to the single largest observation is reported in Section 5.4. A more detailed analysis of the distribution of the residuals would still be needed to better understand the stability of the differences observed between the two groups.

5.3 Directional agreement across volatility regimes:

Table 3: Directional agreement between US sessions and subsequent Indian market opening gaps.

Sample	Same direction match	Usable observations	Direction match (%)
Full sample	152	239	63.6
High VIX	39	61	63.9
Other days	113	178	63.5

Directional agreement is 63.9% for the high-VIX observations and 63.5% for observations with a low value of VIX. This is approximately a 0.4 percentage point difference with rounding. The high-VIX group has a slightly higher level of raw directional agreement, but the difference is small.

The sign tables for each group are:

The majority-sign benchmark for both groups is approximately 59.0%. The observed levels of directional agreement are approximately 4.9 percentage points above the majority-sign benchmark for the high-VIX observations and approximately 4.5 percentage points above the majority-sign benchmark for the low-VIX observations. These differences are descriptive and do not necessarily imply a statistically significant difference.

The directional results are important, as a stronger linear relationship does not necessarily imply a stronger level of directional agreement. Although the correlation, slope, and R^2 values are higher for the high-VIX observations, their level of directional agreement is only slightly higher.

5.4 Sensitivity to the largest observation:

The scatter plot shows one unusually large observation. The Indian trading day of 7 April 2025 is matched to the US session of 4 April 2025. The return in that US session was −4.12%, and the subsequent Nifty 50 opening gap on 7 April 2025 was −5.00%, with a matched VIX closing value of 45.31. Both values are much larger in magnitude than almost all other observations in the sample.

To examine how much this single observation affects the results, the correlation, slope, and R^2 are also computed without it. The observation is kept in the main results, and only the comparison is reported here. For the full sample, removing this observation lowers the correlation from 0.386 to 0.247, the slope from 0.248 to 0.131, and the R^2 from 0.149 to 0.061. For the high-VIX group, to which this observation belongs, the correlation falls from 0.433 to 0.237, the slope from 0.294 to 0.117, and the R^2 from 0.188 to 0.056. The other-day group is not affected because this observation is in the high-VIX group. Directional agreement is almost unchanged at 63.4% for the reduced sample compared to 63.6% for the full sample.

This shows that a noticeable part of the strength of the fitted relationship, especially in the high-VIX group, comes from this single observation. Without this observation, the correlation in the high-VIX group (0.237) is slightly lower than the correlation in the other-day group (0.288). The main results are still reported with the observation included, but this sensitivity limits the strength of the conclusions that can be drawn about H2.

5.5 Assessment of Hypothesis 2:

There is some evidence that there is a stronger fitted relationship during high-VIX periods. The correlation increases from 0.288 to 0.433, the slope increases from 0.172 to 0.294, and the R^2 increases from 0.083 to 0.188.

However, the level of directional agreement only increases slightly from 63.5% to 63.9%. The high-VIX group also has a higher level of dispersion in both variables and a smaller number of observations. The difference between the two groups has not been tested using a formal test for group comparison.

H2 receives some descriptive support. There is evidence that there is a stronger fitted relationship during high-VIX periods in this sample, but this does not necessarily imply that volatility causes this difference or that directional agreement is substantially improved during high-VIX periods. In addition, the sensitivity check in Section 5.4 shows that the difference in correlations between the two groups is partly driven by a single unusually large observation (the Indian trading day of 7 April 2025, matched to the US session of 4 April 2025). Without this observation, the correlation in the high-VIX group is no longer higher than the correlation in the other-day group.

6. Discussion:

The full sample results show a positive relationship between the returns in the US session and opening gaps in India during 2025. The correlation of 0.386 and the positive slope are consistent with the hypothesis that some information captured in the US equity market can also be relevant to the Indian equity market. The average opening gap is positive following a positive US session and negative following a negative US session. This provides additional support for H1.

However, the relationship is incomplete. The R^2 of 0.149 suggests that the one-variable linear model explains approximately 14.9% of the variation in opening gaps in India. A large amount of the variation remains unexplained by the linear model. This is not surprising, as there are a number of influences on India other than information reflected in the US equity market, including Indian domestic news, currency movements, sector-specific information, and other factors that are not included in the regression.

The distinction between association and causality is important in the interpretation of the results. The analysis does not directly address investor behaviour, information propagation, or the effect of US market movements on the Indian market. The positive association may be consistent with information flow between the two markets but could also be driven by a common source of information that affects both markets.

The volatility comparison adds some additional context. There is a higher correlation, slope, and R^2 during high-VIX regimes. This is consistent with a stronger fitted relationship and a closer linear relationship during these periods. However, the standard deviations of both variables are also much higher during high-VIX periods. This could potentially affect the difference in the fitted relationships between the two groups as well as the impact of any extreme values. The sensitivity check in Section 5.4 confirms that one unusually large observation has a noticeable effect on the fitted relationships, especially in the high-VIX group.

Directional agreement is only slightly higher during high-VIX regimes (63.9%) compared to other periods (63.5%). Both of these values are above the majority-sign benchmark, but whether the difference between the observed accuracy and the majority-sign benchmark is statistically significant or whether the relationship would occur in another sample is not addressed.

These results highlight why a single measure should not be used to make a conclusion. The slope describes fitted sensitivity, the correlation describes linear association, the R^2 describes in-sample fit, and the directional agreement describes the same non-zero sign between the two variables. They provide complementary descriptions, but none of these metrics on their own are sufficient to support a causal relationship or a profitable trading strategy.

The date-matching procedure also has some impact on the results. There are 11 intervals during which there are two US sessions during an Indian market closure. The workbook uses the revised rule of taking the most recent completed US session before the Indian opening time. There are also 10 intervals in which no completed US session exists, and therefore these intervals were excluded from the results. These issues have been documented but have an impact on the meaning of the sample. The selected US session in the sample is a practical proxy for the relevant information interval and not necessarily a perfect representation of every movement in US prices that could have influenced the opening gap in India.

Overall, there is a positive descriptive relationship between the returns in the US session and the opening gaps in India. There is also some evidence that a stronger fitted relationship occurs during high-VIX regimes, but the small difference in directional agreement and the lack of formal group comparison tests prevent a stronger conclusion regarding predictive performance.

7. Limitations and Further Research:

There are a number of limitations to the analysis that will impact the interpretation of the results.

First, the sample period is one year (2025). The relationships observed may be specific to this year and may not occur in other economic or volatility regimes. A longer sample period would allow for the relationship to be examined across a broader range of conditions.

Second, the opening gap is a proxy for returns but is not a full return to investors. Dividends, transaction costs, execution prices, and slippage are excluded from the opening gap. This means that it cannot be used to determine if a profitable trading strategy can be implemented based on the relationship observed.

Third, the VIX measures volatility in US equities but not in India. A possible extension would be to use the India VIX to examine the relationship during a period of increased volatility in India. NSE describes India VIX as an indicator of expected near-term Nifty volatility derived from Nifty option prices (National Stock Exchange of India, n.d.).

Fourth, only the US-session return is included in the regression. It does not account for domestic news in India, currency movements, commodity prices, interest rate expectations, or any other factors. These factors may contribute to the relationship observed.

Fifth, there are some decisions made in the date-matching that have an impact on the results. The workbook documents the ten intervals that were excluded, as well as the eleven intervals in which there were two US sessions during an Indian market closure and used the most recent completed US session before the Indian opening. A manual check sheet for the ten excluded intervals has been provided, but an independent check using exchange calendars and time zone-aware timestamps has not been performed. A future extension could automate and independently verify the date-matching for all observations.

Sixth, the high-VIX group has 61 observations and the low-VIX group has 178 observations. The smaller group may be more sensitive to influential observations. A formal test of the difference in the correlation or slope between the two groups has not been performed. A sensitivity check that removes the single largest observation is reported in Section 5.4 and shows that this observation has a noticeable effect on the full-sample and high-VIX results.

Finally, the analysis is in-sample and is descriptive. It does not determine whether the model can be used to predict opening gaps in India. A future extension could include a longer sample, other explanatory variables, sector-specific analysis such as Nifty IT and Nifty Bank, or examine a predefined trading strategy on out-of-sample data.

These extensions would build on the results of this study without assuming that a positive relationship must occur or that a stronger in-sample fit necessarily translates to improved out-of-sample prediction.

8. Conclusion:

The objective of this study was to determine the extent to which returns in the US session are related to opening gaps in India during 2025 and whether this relationship differs during a period of increased US expected volatility.

Across 239 observations, the correlation was 0.386, and the regression slope was 0.248. The fitted linear model had an R^2 of 0.149, suggesting that it explains approximately 14.9% of the variation in opening gaps in India. Opening gaps were also positive following a positive return in the US session and negative following a negative return in the US session. Directional agreement was 63.6%. These results provide some support for H1. There is a positive relationship between the two variables in the sample, but the US-session return only provides an incomplete explanation of the variation in opening gaps in India.

There is also some evidence that the fitted relationship is stronger during high-VIX periods. The correlation for the high-VIX group is 0.433 compared to 0.288 for the low-VIX group. The slope is 0.294 compared to 0.172 for the low-VIX group. The R^2 is 0.188 compared to 0.083 for the low-VIX group. These results suggest a stronger fitted linear relationship during high-VIX periods. However, directional agreement was 63.9% for the high-VIX group and 63.5% for the low-VIX group. This is not a substantial improvement in directional agreement.

These results should be interpreted as descriptive evidence but not as causal or as a profitable trading strategy. Whether the differences between the two groups are statistically significant, whether the relationship would hold on a different sample, or whether the relationship can be used to predict opening gaps in India is not addressed. A sensitivity check also shows that the strength of the fitted relationship is partly driven by one unusually large observation, the Indian trading day of 7 April 2025 (Section 5.4).

The most defensible conclusion is that there is a positive relationship between returns in the US session and opening gaps in India across the 2025 sample and that this fitted relationship is stronger during high-VIX periods. However, the relationship is incomplete, and the robustness of the relationship and its ability to predict opening gaps in India requires further research.

9. References:

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