# Do Stocks Have a "Memory"? Evidence from the Indian Stock Market

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## Abstract

**This paper predicted the price movement of Nifty 50 stocks on the Indian stock market using probability theory. It answered the question, what is the probability of a consecutive up day for a stock after a previous up day, where an up day refers to a trading day on which the closing price of a stock was greater than its previous day's closing price. It further found out the probability of a consecutive up day for a stock after two, three, four, and five previous up days, respectively. We used Bayes' theorem to calculate this. The period of study was from May 17, 2018 to August 10, 2018. The results showed that for some stocks, the probability of a consecutive up day after previous up days was not the same as having a "normal" up day (an up day not conditioned on any previous event whatsoever). This meant that some stocks had a "memory" and their previous up days could be used to predict their future up/down days. The findings of this paper would help both retail and institutional investors make better trading decisions.**

***Keywords:*** **Bayes' theorem, conditional probability, Indian stock market, Nifty 50, Up day**

**JEL Classification: C02, C11, C12**

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According to Levin, Rubin, Rastogi, and Siddiqui (1998), "Bayes' theorem offers a powerful statistical method of evaluating new information and revising our prior estimates (based upon limited information only) of the probability that things are in one state or another" (p. 193). It states that if an event $X$ corresponds to a number of $m$ mutually exclusive and exhaustive events $Y_1, Y_2, \ldots, Y_m$, which constitute a part of the sample space $S$, and if $P(Yk)$ and $P(X \mid Yk)$ are given, then :

$$P(Yk|X) = \frac{P(Yk) \times P(X|Yk)}{\Sigma i\, P(Yi) \times P(X|Yi)} \qquad (1)$$

The probabilities $P(Yk)$, $k = 1, 2, 3, \ldots, m$ are called *apriori probabilities*, since they exist even before the experiment is conducted.

The probabilities $P(X \mid Yk)$, $k = 1, 2, 3, \ldots, m$ are called *posterior probabilities*, since they are found as a result of the experiment.

Intuitively, Bayes' theorem is used to update our belief about a hypothesis after obtaining some new information. It helps to compute $P(Yk \mid X)$ directly, given that we have information about $P(X \mid Yk)$.

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This paper uses Bayes' theorem to find the probability of a consecutive up day for a stock after a previous up day (where an up day refers to a trading day on which the closing price of a stock is greater than its previous day's closing price). It further finds out the probability of a consecutive up day for a stock after two, three, four, and five previous up days respectively, using Bayes' theorem.

## Literature Review

To achieve our research objective, it was necessary to answer the question, "do stock markets exhibit trends?" In other words, are markets inefficient to some extent? After all, it would be unreasonable to try and predict stock price movement in a purely efficient market. Through a survey of related literature, we found that Niederhoffer and Osborne(1966) examined the existence of market trends in high-frequency data using probabilities. For the stock that they had examined, there was a higher probability for the current price change to reverse directions from the previous price change as opposed to moving in the same direction. Rechenthin (2014) stated that much of the existence of predictability in Niederhoffer and Osborne(1966) could be explained through the bouncing of prices between the bid-ask spread.

In another paper, Alexander (1964) attempted to show market predictability by creating profits through buying and selling using quantitative rules based on past prices. Timmermann and Granger (2004) proposed that the efficient market hypothesis could be violated due to the existence of a single successful trading model. Studies conducted by Neely, Weller, and Dittmar (1997) ; Chang and Osler (1999) ; Levich and Thomas (1993) ; and Sweeney (1988) found profitability of trading rules, and thus, showed market predictability, at least part of the time. Ohira, Sazuka, Marumo, Shimizu, Takayasu, and Takayasu (2002) ; Tanaka-Yamawaki (2003) ; Sazuka (2006) ; and Hashimoto, Ito, Ohnishi, Takayasu, Takayasu, and Watanabe (2012) found extremely high predictability levels of market data at the trade-by-trade (tick data) level. Also, Ryaly, Kumar, and Urlankula (2014) and Inegbedion (2012) found some market inefficiency. The consensus of these papers is that markets are predictable, at least to some extent.

## Data

We collected adjusted closing price data of Nifty 50 stocks on the Indian stock market using a Bloomberg terminal for the period January 2, 2008 to March 2, 2017.

## Methodology

Bayes' theorem can be expressed mathematically as follows :

Let $Y_1, Y_2, \ldots, Y_m$ be $m$ mutually exclusive and exhaustive events which constitute a part of the sample space $S$.

$$Yi \cap Yj = \emptyset \text{ for } i \neq j$$
$$S = Y1 \cup Y2 \cup \ldots \cup Ym$$

Let us assume that the prior probabilities of the events $Y_1, Y_2, \ldots, Y_m$ are positive. Now, if $X$ is an event, then $X$ can be written as the union of $m$ mutually exclusive events as follows :

$$X = (X \cap Y1) \cup (X \cap Y2) \cup \ldots \cup (X \cap Ym) \qquad (2)$$

Therefore,

$$P(X) = P(X \cap Y1) + P(X \cap Y2) + \ldots + P(X \cap Ym)$$

$$P(X) = \Sigma i\, P(X \cap Yi)$$
$$P(X) = \Sigma i\, P(Yi) \times P(X \mid Yi) \qquad (3)$$

So, if $P(X) > 0$, the posterior probability of event $Y_k$ given that event $X$ has already occurred is :

$$P(Yk \mid X) = \frac{P(Yk \cap X)}{P(X)} \quad \frac{P(Yk) \times P(X \mid Yk)}{\Sigma i\, P(Yi) \times P(X \mid Yi)} \qquad (4)$$

Based on Bayes' theorem, we calculated the probability of a consecutive up day for a stock after previous up days as follows :

$$P(i+_j \mid i+_{j-1}) = \frac{P(i+_j \cap i+_{j-1})}{P(i+_{j-1})} = \frac{P(i+_j) \times P(i+_{j-1} \mid i+_j)}{P(i+_{j-1})} \qquad (5)$$

where,

$i+_j$ is an event corresponding to an up day for the $i^{th}$ stock and $j = 1, 2, 3, \ldots, 6$, respectively,

$I+_{j-1}$ is an event corresponding to $j$-1 previous up days for the $i^{th}$ stock.

Probability of a "normal" up day was calculated as follows :

$$P(\text{normal up day}) = \frac{(\text{total number of up days})}{(\text{total number of trading days})} \qquad (6)$$

## Empirical Analysis and Results

The following tables represent the probabilities calculated for the Nifty 50 stocks, using the methodology described above. Also, the Nifty 50 stocks are divided into their respective industrial sectors in the tables that follow :

Table 1 shows that *P* (up day/ previous five up days) > *P* (normal up day) for Bajaj Auto Ltd. and *P* (up day/ previous five up days) < *P* (normal up day) for Mahindra & Mahindra Ltd. and Maruti Suzuki India Ltd. This means that if Bajaj Auto Ltd. has five consecutive up days, there is a high chance for it to have an up day on the following day and if any one of Mahindra & Mahindra Ltd. and Maruti Suzuki India Ltd. has five consecutive up days, there is a high chance for that stock to have a down day on the following day. For the rest of the stocks,

**Table 1. Probability Table for the Automobile Sector**

| Company Name | *P* (normal up day) | *P* (up day/ previous up day) | *P* (up day/ previous 2 up days) | *P* (up day/ previous 3 up days) | *P* (up day/ previous 4 up days) | *P* (up day/ previous 5 up days) |
|---|---|---|---|---|---|---|
| Bajaj Auto Ltd. | 0.48 | 0.52 | 0.53 | 0.54 | 0.52 | **0.57** |
| Bosch Ltd. | 0.49 | 0.51 | 0.50 | 0.50 | 0.55 | 0.53 |
| Eicher Motors Ltd. | 0.51 | 0.53 | 0.56 | 0.54 | 0.52 | 0.47 |
| Hero MotoCorp Ltd. | 0.51 | 0.52 | 0.51 | 0.49 | 0.47 | 0.50 |
| Mahindra & Mahindra Ltd. | 0.51 | 0.50 | 0.51 | 0.48 | 0.45 | **0.39** |
| Maruti Suzuki India Ltd. | 0.51 | 0.50 | 0.47 | 0.46 | 0.47 | **0.40** |
| Tata Motors Ltd. | 0.50 | 0.51 | 0.51 | 0.51 | 0.47 | 0.46 |

**Table 2. Probability Table for the Cement Sector**

| Company Name | *P* (normal up day) | *P* (up day/ previous up day) | *P* (up day/ previous 2 up days) | *P* (up day/ previous 3 up days) | *P* (up day/ previous 4 up days) | *P* (up day/ previous 5 up days) |
|---|---|---|---|---|---|---|
| ACC Ltd. | 0.49 | 0.49 | 0.48 | 0.48 | 0.43 | **0.39** |
| Ambuja Cements Ltd. | 0.49 | 0.49 | 0.48 | 0.50 | 0.49 | 0.47 |
| Grasim Industries Ltd. | 0.50 | 0.49 | 0.49 | 0.51 | 0.45 | 0.45 |
| Ultra Tech Cement Ltd. | 0.51 | 0.51 | 0.49 | 0.52 | 0.53 | 0.50 |

**Table 3. Probability Table for the Construction Sector**

| Company Name | *P* (normal up day) | *P* (up day/ previous up day) | *P* (up day/ previous 2 up days) | *P* (up day/ previous 3 up days) | *P* (up day/ previous 4 up days) | *P* (up day/ previous 5 up days) |
|---|---|---|---|---|---|---|
| Larsen & Toubro Ltd. | 0.49 | 0.52 | 0.51 | 0.49 | 0.50 | 0.44 |

**Table 4. Probability Table for the Consumer Goods Sector**

| Company Name | *P* (normal up day) | *P* (up day/ previous up day) | *P* (up day/ previous 2 up days) | *P* (up day/ previous 3 up days) | *P* (up day/ previous 4 up days) | *P* (up day/ previous 5 up days) |
|---|---|---|---|---|---|---|
| Asian Paints Ltd. | 0.52 | 0.53 | 0.50 | 0.48 | 0.46 | 0.50 |
| Hindustan Unilever Ltd. | 0.50 | 0.47 | 0.48 | 0.49 | 0.48 | **0.41** |
| I T C Ltd. | 0.52 | 0.51 | 0.52 | 0.53 | 0.54 | 0.51 |

**Table 5. Probability Table for the Energy Sector**

| Company Name | *P* (normal up day) | *P* (up day/ previous up day) | *P* (up day/ previous 2 up days) | *P* (up day/ previous 3 up days) | *P* (up day/ previous 4 up days) | *P* (up day/ previous 5 up days) |
|---|---|---|---|---|---|---|
| Bharat Petroleum Corporation Ltd. | 0.50 | 0.49 | 0.46 | 0.47 | 0.53 | 0.48 |
| GAIL (India) Ltd. | 0.49 | 0.48 | 0.45 | 0.43 | 0.44 | **0.40** |
| NTPC Ltd. | 0.49 | 0.47 | 0.46 | 0.48 | 0.49 | 0.51 |
| Oil & Natural Gas Corporation Ltd. | 0.50 | 0.49 | 0.49 | 0.45 | 0.46 | 0.48 |
| Power Grid Corporation of India Ltd. | 0.50 | 0.48 | 0.49 | 0.47 | **0.42** | 0.48 |
| Reliance Industries Ltd. | 0.49 | 0.49 | 0.48 | 0.47 | 0.45 | 0.45 |
| Tata Power Co. Ltd. | 0.49 | 0.49 | 0.50 | 0.48 | 0.45 | 0.53 |

*P* (up day/ previous up days) is roughly equivalent to their corresponding *P* (normal up day) and hence, their previous up days cannot be used to predict their future up days.

The Table 2 shows that *P* (up day/ previous five up days) < *P* (normal up day) for ACC Ltd. This means that if this stock has five consecutive up days; there is a high chance for it to have a down day on the following day. For the rest of the stocks, *P*(up day/ previous up days) is roughly equivalent to their corresponding *P* (normal up day) and hence, their previous up days cannot be used to predict their future up days.

The Table 3 shows that *P* (up day/ previous up days) is roughly equivalent to *P* (normal up day) for Larsen & Toubro Ltd. This means that previous up days cannot be used to predict the future up days for this stock.

The Table 4 shows that *P* (up day/ previous five up days) < *P* (normal up day) for Hindustan Unilever Ltd. This means that if Hindustan Unilever Ltd. has five consecutive up days, there is a high chance for it to have a down

**Table 6. Probability Table for the Financial Services Sector**

| Company Name | *P* (normal up day) | *P* (up day/ previous up day) | *P* (up day/ previous 2 up days) | *P* (up day/ previous 3 up days) | *P* (up day/ previous 4 up days) | *P* (up day/ previous 5 up days) |
|---|---|---|---|---|---|---|
| Axis Bank Ltd. | 0.50 | 0.52 | 0.50 | 0.46 | 0.48 | 0.51 |
| Bank of Baroda | 0.50 | 0.50 | 0.48 | 0.46 | 0.46 | 0.47 |
| HDFC Bank Ltd. | 0.51 | 0.50 | 0.48 | 0.48 | 0.51 | 0.53 |
| Housing Development Finance Corporation Ltd. | 0.49 | 0.50 | 0.52 | 0.49 | 0.49 | 0.47 |
| ICICI Bank Ltd. | 0.50 | 0.54 | 0.52 | 0.52 | 0.52 | 0.47 |
| IndusInd Bank Ltd. | 0.52 | 0.51 | 0.50 | 0.48 | **0.45** | **0.42** |
| Kotak Mahindra Bank Ltd. | 0.51 | 0.50 | 0.51 | 0.51 | 0.52 | 0.53 |
| State Bank of India | 0.51 | 0.53 | 0.53 | 0.53 | 0.52 | 0.52 |
| Yes Bank Ltd. | 0.51 | 0.54 | 0.51 | 0.55 | 0.53 | 0.54 |

**Table 7. Probability Table for the Industrial Manufacturing Sector**

| Company Name | *P*(normal up day) | *P*(up day/ previous up day) | *P*(up day/ previous 2 up days) | *P*(up day/ previous 3 up days) | *P*(up day/ previous 4 up days) | *P*(up day/ previous 5 up days) |
|---|---|---|---|---|---|---|
| Bharat Heavy Electricals Ltd. | 0.49 | 0.50 | 0.50 | 0.47 | **0.39** | **0.37** |

**Table 8. Probability Table for the Information Technology Sector**

| Company Name | *P* (normal up day) | *P* (up day/ previous up day) | *P* (up day/ previous 2 up days) | *P* (up day/ previous 3 up days) | *P* (up day/ previous 4 up days) | *P* (up day/ previous 5 up days) |
|---|---|---|---|---|---|---|
| HCL Technologies Ltd. | 0.52 | 0.51 | 0.52 | 0.48 | **0.44** | **0.36** |
| Infosys Ltd. | 0.51 | 0.52 | 0.49 | 0.48 | 0.50 | 0.47 |
| Tata Consultancy Services Ltd. | 0.51 | 0.52 | 0.50 | 0.49 | 0.46 | **0.35** |
| Tech Mahindra Ltd. | 0.51 | 0.51 | 0.50 | 0.46 | 0.47 | **0.38** |
| Wipro Ltd | 0.52 | 0.52 | 0.49 | 0.48 | **0.43** | **0.45** |

day on the following day. For rest of the stocks, *P* (up day/ previous up days) is roughly equivalent to their corresponding *P*(normal up day) and hence, their previous up days cannot be used to predict their future up days.

The Table 5 shows that *P* (up day/ previous five up days) < *P* (normal up day) for GAIL (India) Ltd. and *P* (up day/ previous four up days) < *P* (normal up day) for Power Grid Corporation of India Ltd. This means that if GAIL (India) Ltd. has five consecutive up days, there is a high chance for it to have a down day on the following day and if Power Grid Corporation of India Ltd. has four consecutive up days, there is a high chance for it to have a down day on the following day. For the rest of the stocks, *P* (up day/ previous up days) is roughly equivalent to their corresponding *P* (normal up day) and hence, their previous up days cannot be used to predict their future up days.

The Table 6 shows that *P* (up day/ previous five up days) < *P*(normal up day) and *P* (up day/ previous four up days) < *P* (normal up day) for IndusInd Bank Ltd. This means that if this stock has either four or five consecutive up days, there is a high chance for it to have a down day on the following day. For rest of the stocks, *P* (up day/ previous up days) is roughly equivalent to their corresponding *P* (normal up day) and hence, their previous up days cannot be used to predict their future up days.

The Table 7 shows that *P* (up day/ previous five up days) < *P* (normal up day) and *P* (up day/ previous four up

**Table 9. Probability Table for the Media and Entertainment Sector**

| Company Name | *P*(normal up day) | *P*(up day/ previous up day) | *P*(up day/ previous 2 up days) | *P*(up day/ previous 3 up days) | *P*(up day/ previous 4 up days) | *P*(up day/ previous 5 up days) |
|---|---|---|---|---|---|---|
| Zee Entertainment Enterprises Ltd. | 0.50 | 0.49 | 0.46 | **0.43** | **0.37** | **0.27** |

**Table 10. Probability Table for the Metals Sector**

| Company Name | *P* (normal up day) | *P* (up day/ previous up day) | *P* (up day/ previous 2 up days) | *P* (up day/ previous 3 up days) | *P* (up day/ previous 4 up days) | *P* (up day/ previous 5 up days) |
|---|---|---|---|---|---|---|
| Coal India Ltd. | **0.35** | 0.50 | 0.49 | 0.44 | 0.44 | **0.38** |
| Hindalco Industries Ltd. | 0.49 | 0.49 | 0.50 | 0.47 | **0.38** | **0.37** |
| Tata Steel Ltd. | 0.50 | 0.50 | 0.51 | 0.49 | 0.46 | **0.42** |

**Table 11. Probability Table for the Pharmaceuticals Sector**

| Company Name | *P* (normal up day) | *P* (up day/ previous up day) | *P* (up day/ previous 2 up days) | *P* (up day/ previous 3 up days) | *P* (up day/ previous 4 up days) | *P* (up day/ previous 5 up days) |
|---|---|---|---|---|---|---|
| Aurobindo Pharma Ltd. | 0.51 | 0.50 | 0.52 | 0.51 | 0.50 | 0.45 |
| Cipla Ltd. | 0.49 | 0.45 | 0.44 | 0.47 | 0.45 | 0.45 |
| Dr Reddy's Laboratories Ltd. | 0.52 | 0.52 | 0.51 | 0.52 | 0.57 | 0.52 |
| Lupin Ltd. | 0.52 | 0.51 | 0.48 | 0.47 | 0.46 | **0.44** |
| Sun Pharmaceutical Industries Ltd. | 0.52 | 0.51 | 0.51 | 0.53 | 0.51 | 0.48 |

days) < *P* (normal up day) for Bharat Heavy Electricals Ltd. This means that if this stock has either four or five consecutive up days, there is a high chance for it to have a down day on the following day.

Table 8 shows that *P* (up day/ previous five up days) < *P*(normal up day) and *P*(up day/ previous four up days) < *P*(normal up day) for HCL Technologies Ltd. and Wipro Ltd. This means that if any one of HCL Technologies Ltd. and Wipro Ltd. has either four or five consecutive up days, there is a high chance for the stock to have a down day on the following day. The table also shows that *P* (up day/ previous five up days) < *P* (normal up day) for Tata Consultancy Services Ltd. and Tech Mahindra Ltd. This means that if any one of these stocks has five consecutive up days, there is a high chance for that stock to have a down day on the following day. It can also be seen that *P* (up day/ previous up days) is roughly equivalent to *P* (normal up day) for Infosys Ltd. This means that previous up days cannot be used to predict the future up days for this stock.

Table 9 shows that *P* (up day/ previous five up days) < *P* (normal up day), *P* (up day/ previous four up days) < *P* (normal up day) and *P* (up day/ previous three up days) < *P* (normal up day) for Zee Entertainment Enterprises Ltd. This means that if this stock has three, four or five consecutive up days; there is a high chance for it to have a down day on the following day.

Table 10 shows that *P* (normal up day) for Coal India Ltd. is quite less when compared with *P* (normal up day) for other stocks, which means that this stock has more down days than up days for the chosen sample period. Further, *P* (up day/ previous five up days) is roughly equivalent to *P* (normal up day) for this stock, but still if it has five consecutive up days, there is a high chance for it to have a down day on the following day. This is due to the fact that its *P* (normal up day) is quite different from a probability value of 0.50. The table also shows that *P* (up day/ previous five up days) < *P* (normal up day) and *P* (up day/ previous four up days) < *P* (normal up day) for

**Table 12. Probability Table for the Services Sector**

| Company Name | *P* (normal up day) | *P* (up day/ previous up day) | *P* (up day/ previous 2 up days) | *P* (up day/ previous 3 up days) | *P* (up day/ previous 4 up days) | *P* (up day/ previous 5 up days) |
|---|---|---|---|---|---|---|
| Adani Ports & Special Economic Zone Ltd. | 0.48 | 0.50 | 0.49 | 0.49 | 0.45 | 0.47 |

**Table 13. Probability Table for the Telecommunications Sector**

| Company Name | *P*(normal up day) | *P*(up day/ previous up day) | *P*(up day/ previous 2 up days) | *P*(up day/ previous 3 up days) | *P*(up day/ previous 4 up days) | *P*(up day/ previous 5 up days) |
|---|---|---|---|---|---|---|
| Bharti Airtel Ltd. | 0.49 | 0.46 | 0.44 | 0.43 | **0.38** | **0.32** |
| Bharti Infratel Ltd. | **0.23** | 0.53 | 0.53 | 0.53 | 0.54 | **0.65** |
| Idea Cellular Ltd. | 0.50 | 0.50 | 0.48 | 0.48 | 0.48 | 0.47 |

Hindalco Industries Ltd., which means that if it has either four or five consecutive up days, there is a high chance for it to have a down day on the following day. Also, *P* (up day/ previous five up days) < *P* (normal up day) for Tata Steel Ltd., which means that if this stock has five consecutive up days, there is a high chance for it to have a down day on the following day.

Table 11 shows that *P* (up day/ previous five up days) < *P*(normal up day) for Lupin Ltd. This means that if this stock has five consecutive up days; there is a high chance for it to have a down day on the following day. For rest of the stocks, *P* (up day/ previous up days) is roughly equivalent to their corresponding *P* (normal up day.) Hence, their previous up days cannot be used to predict their future up days.

Table 12 shows that *P* (up day/ previous up days) is roughly equivalent to *P* (normal up day) for Adani Ports and Special Economic Zone Ltd. This means that previous up days cannot be used to predict the future up days for this stock.

Table 13 shows that *P* (up day/ previous five up days) < *P* (normal up day) and *P* (up day/ previous four up days) < *P* (normal up day) for Bharti Airtel Ltd. This means that if this stock has either four or five consecutive up days, there is a high chance for it to have a down day on the following day. The table also shows that *P* (normal up day) for Bharti Infratel Ltd. is quite less when compared with *P* (normal up day) for other stocks, which means that this stock has more down days than up days for the chosen sample period. Further, *P* (up day/ previous five up days) >> *P* (normal up day) for this stock, which means that if it has five consecutive up days, there is a high chance for it to have an up day on the following day. For Idea Cellular Ltd., *P* (up day/ previous up days) is roughly equivalent to its corresponding *P* (normal up day) and hence, previous up days cannot be used to predict future up days for this stock.

## Research Implications and Conclusion

The findings of this paper would help both retail and institutional investors make better trading decisions by predicting whether a stock would yield positive or negative returns given information about previous days' positive returns.

This paper used Bayes' theorem to predict the price movement of Nifty 50 stocks on the Indian stock market. A prerequisite to achieve this research objective was to find an answer to the question - do stock markets exhibit trends? In other words, are markets inefficient to some extent ? Through a survey of related literature, we found that markets are predictable, at least to some extent. We then used Bayes' theorem to calculate the probability of a

consecutive up day after previous up days for Nifty 50 stocks on the Indian stock market. The results show that for some stocks, the probability of a consecutive up day after previous up days is not the same as having a "normal" up day. This means that some stocks have a "memory" and their previous up days can be used to predict their future up/down days.

## Limitations of the Study and Scope for Further Research

This study found out the probability of a consecutive up day after previous up days for Nifty 50 stocks on the Indian stock market. Future studies can enhance the scope of this line of work by finding out the probability of a consecutive up day after previous down days for Indian stocks. This study also considered a time horizon of approximately 9 years. Future studies can take a longer time period into consideration.

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