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RESEARCH ARTICLE

ANALYSIS OF STOCK MARKET PRICE BEHAVIOUR: A MARKOV CHAIN APPROACH

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ABSTRACT

Stock market prediction has proved to be of vital importance in the present day economic scenario and stochastic process can be very effectively applied in forecasting the market trend. This paper attempts to analyse the behaviours of stock price of State Bank of India, one of the leading commercial bank of India for 1035 days covering the period from 21st March 2011 to 20th March 2015. The secondary data on daily closing price of shares for are collected from Historical price of share– Yahoo Finance. In order to meet the objectives of the paper, the investigators will propose to find out the long term behaviour of the share, expected number of visits to a particular state, and expected first reaching time of different states. The Markov Chain model is applied to analyse and predict the stock behaviour considering three different states, 'up'– when the share price increase, 'down'– when the share price decrease and 'remain same'– when share price gets unchanged. The Markov Chain model is a probability model based on transition probability matrix and initial state vector. By observing the number of transitions from one state to another, the transition probability matrix has been obtained. The study reveals that regardless of bank's current share price steady state probabilities of share 'up', 'down' and 'remain same' for SBI are 46.99%, 49.81% and 3.19% respectively. It is observed that if the closing value of SBI share is in the state 'up' in the day one then it can be expected to return to the state 'up' for the first time at the third day.

INTRODUCTION

In the fast growing economy of recent times, stock market plays a significant role in the organization of various business houses in the form of companies and caters to the need of raising the fund and capital formation for those companies. Companies use to sell their shares to individuals or group of individuals which are known as stocks. The stock exchange is the legal platform where such stocks are traded in. The stock market refers to a very broader term which covers the entire globe through wider economic activities of trading.

The purchase of stock by individual or group of individuals is motivated by the desire for making profit. Generally, the companies making more profit offer high amount of money to the investors in comparison to the companies making less profit or no profit. The price of the shares grows up or rises in the stock market according to the performance of the companies. The procedure is reversed in case of the less profit making companies, generating demands to the stocks of those making profits. This leads to an imbalance in the demand and supply of stocks in trade. Under such circumstances unscrupulous methods are applied by companies through window dressing, which produces the high risk of loss to the stock holders in the long run. However apart from the above, worldwide trend of business, natural calamities and the socio-political policy adopted by rich economy or rich region also affects the balance between demand and supply of stocks.

Thus there lies the significance of stock market prediction which may benefit the stock holders and investors. Various scientific methods have been proposed and implemented for stock market prediction through the analysis of past information. People related to stock market are interested to know the future occurrence of the market. However the fluctuating nature of stock market makes the analysis and prediction a complex phenomenon. The inherent changes involved in the whole process highly affect the investor's behaviour, and making accurate prediction of stock market by any single method a very difficult job. Different methods such as Moving average, Regression analysis, Data mining, Markov chain analysis, Hidden Markov Model, Weighted Markov chain are used by different researchers to forecast the stock market.

LITERATURE REVIEW

Stochastic model is used by many researchers to predict and analyse the stock market behaviours in different times.

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Zhang & Zhang (2009) introduced a Markov chain model for stock market trend forecasting in the Chinese stock market. The study revealed that Markov chain model has no after effect and the method was more effective to analyse and predict the stock market index and closing stock price under the market mechanism. By applying Markov chain model they achieved relatively good results and suggested that this model should be applied to other fields such as future market and the bond market. They also suggested that investors should combine the results of forecasts from using Markov chain to predict with other factors and see as a basis for decision making. Escoghene (2011) studied long run prospects of security prices in Nigeria where the data were collected from the randomly selected banks from the banking sector of Nigeria.

The analysis suggested that the price level of Nigerian bank were likely to remain relatively stable in the long run irrespective of the current situations. It was expressed that the technique will add to the very rich and often conflicting literature on stock price prediction decrease and remains unchanged in future. Onwukwe and Samson (2014) examined the long run behaviour of the closing price of shares of eight Nigerian banks using Markov chain model. They computed limiting distribution transition probability matrix of the of share price and found that despite of the current situation in the market there is a hope for Nigerian bank stocks. They concluded that the results derive from the study will be useful to investors, intending investors and the other relevant stakeholders who were involve in the stock market. Simeyo *et al*. (2015) applied Markov chain to model and forecast the trend of Safaricom share trading in Nairobi, Securities Exchange, of Kenya. They derived the initial state vector and the transition probability matrix and used them to predict the stats of share price accurately. They also found long-term behaviour of the share price. Moreover Zhou (2015) used Weighted Markov chain, Tsai and Cheu, Lee and Shin, Hassan and Nath (2005) used Hidden Markov model to predict and forecast the stock market price.

The proposed work is an attempt to analyse the behaviour of the stocks of State Bank of India in the line of aforesaid works of the authors.

Objectives of the study

In this paper the Markov Chain model has been applied to forecast and analyse the behaviour of SBI shares based on the past information. The objectives of the study are (i) to study the long-term behaviour of stocks, (ii) to find out the expected number of visits to a particular state, and (iii) to find out the expected first reaching time of different states.

Basic theory of Markov chain model

Markov process is a special type stochastic process for which the future occurrence of any event depends only on present state. The set of values that Markov process takes is known as its state space. Depending on the values of state space the process may be discrete or continuous. The process with discrete state space is known as Markov chain. Markov chain is one of the most well developed theories of stochastic process, with wider applications in the field of physical, biological, economical and social phenomena.

Markov Chain

The stochastic process $\{X_n\}$, n=0, 1, 2... with discrete state space **S** is called Markov Chain if it satisfies the Markov property.

That is for any i, j, $i_1, i_2 \ldots i_{n-1} \in \mathbf{S}$

$$P_r\{x_{n+1}=j \mid x_n = i, x_{n-1} = i_{n-1}, \ldots, x_1 = i, x_0 = i_0\}$$
$$= P_r\{x_{n+1} = j \mid x_n = i\}$$

Transition Probability and Transition Matrix

The transition probability p_{ij} is the probability of moving from state i in n^{th} trial, to the state j in $(n+1)^{th}$ trial. Thus

$$p_{ij} = P_r\{X_{n+1} = j \mid X_n = i\},$$

for all i, j $\in$ **S** and n≥0 is the one step transition probability. These transition probabilities represented in a matrix form known as transition probability matrix and written as

$$\mathbf{P} = [p_{ij}]_{n \times n} \quad \text{where} \quad \sum_{j=1}^{n} p_{ij}=1 \ \forall i \text{ and } \ 0<p_{ij}<1$$

All the possible states of the Markov Chain are used as rows and columns, so transition probability matrix is always a square matrix and the row sum is always one.

The probability

$p_{ij}^{(k)} = \Pr\{X_{n+k} = j \mid X_n = i\} \ \forall\, k>0\ n\geq 0,\ i\ \ j \in \mathbf{S}$

is the k step transition probability of state i to state j in k steps. In the matrix form it is represented as

$$\mathbf{P}^{(k)} = [p_{ij}^{(k)}]_{i, j \in S} \ \ \forall\, k>0.$$

And the $p_{ij}^{(k)}$ is the $(i, j)^{th}$ element of the matrix $\mathbf{P}^{(k)}$. If the chain is time homogeneous, then it is independent of n and

$$\mathbf{P}^{(k)} = \mathbf{P}^k \qquad \text{for all } k$$

The initial distribution of Markov chain at time 0 is defined as

$$®^{(0)} = [P_r\{X_0=i\}]_{i \in \mathbf{S}} \text{ and}$$
$$®^{(n)} = [P_r\{X_n=i\}]_{i \in \mathbf{S}} = [\pi_i^{(n)}]_{i \in \mathbf{S}},$$

which is the row vector of probabilities at time n. This initial distribution is needed along with transition probability matrix to understand the chain fully.

Now $®^{(n)} = ®^{(n-1)}\mathbf{P} = ®^{(n-2)}\mathbf{PP} = ®^{(n-2)}\mathbf{P}^2$

or $®^{(n)} = ®^{(0)}\mathbf{P}^n \ \forall\, n\geq 0.$

The elements of ® are the elements of unique solution of **π=®P** and $\sum \pi_i=1$

Regular Markov Chain: A Markov chain is called regular if some power of the transition matrix contains only positive elements.

Irreducible Markov Chain: The chain having only one class is called irreducible Markov chain.

Limiting Distribution: If for any sequence of distribution $\{\pi_n\}_{n = 0, 1, ...}$ $\lim_{n \to \infty}$ ®$^{(n)}$ = ® and the $\sum \pi_i = 1$ then π is called the limiting distribution of the chain.

Steady state: If at any step n, $\boldsymbol{\pi}^{(n)} = \boldsymbol{\pi}$ then it is said that the chain has reached the steady state or equilibrium and π is called the steady state distribution. This ® may be dependent or independent of initial distribution ®$^{(0)}$. If ® exists and is independent of initial distribution then the sequence of matrices $\{\mathbf{P}^{(n)}\}_{n=1, 2, ...}$ must converges to a matrix $\mathbf{P}^{(\infty)}$,in which all rows are equal to ®. That is

$$m^{(\infty)} = \lambda\iota\mu_{v \to \infty}\ m^{(v)} = \begin{pmatrix} \pi \\ \pi \\ \vdots \end{pmatrix}$$

This is the basis of finding the long-term behaviour of the chain.

Expected Number of visits

The expected number of visits made by the chain to state j in first n steps is

$\mathbf{E}\,[\mathbf{v}_{ij}{}^{(n)}] = \dot{g}\mathbf{P}_{ij}{}^{(k)}$ where v_{ij} denote the number of visits made by the chain to state j in first n steps (step 0 to step (n–1)) from state i. In matrix form

$$\mathbf{V}^{(n)} = [\mathbf{E}\,[v_{ij}{}^{(n)}]]_{i\,j\, \in S} = \dot{g}\mathbf{P}^{(k)} = \dot{g}\ \mathbf{P}^{k} \quad \begin{matrix} n-1 & & n-1 \\ k=1 & & k=1 \end{matrix}$$

The expected number of visits to the state j throughout the life time of the chain is

$$\mathbf{E}\,[\mathbf{v}_{ij}] = \lim_{n \to \infty} \mathbf{E}\,[\mathbf{v}_{ij}{}^{(n)}]$$

Expected First Reaching time

If n_{ij} be the number of steps before a chain reaches state j for the first time starting from state i , then n_{ij} is called the first reaching time from state i to state j. The expected value $\mathbf{E}\,(n_{ij}) = \mathbf{E}\,(T_j|x_0{=}i)$ is defined as the expected first reaching time of the states. If $\mathbf{N}{=}\mathbf{E}(n_{ij})$, then using first step analysis the expected first reaching time can be represented in the matrix form as

$$\mathbf{N = E + P\,(N–N_d)}$$

Expected Return time

The first reaching time $n_{jj} = n_j$ is called the return time or the duration of visits to state j starting from the state j. If $\mathbf{E}\,(n_j) = \mathbf{E}\,(n_{jj})$, then it is defined as the expected return time for the state j to the state j. For a finite irreducible chain the expected return time to a state j, $j \in S$ is the reciprocal of visiting rate of the chain. Therefore

$\mathbf{E}\,(n_j) = 1/\pi_{ij}$

METHODOLOGY

For the purpose of the study, the secondary data on daily closing price of share of SBI are collected from Historical Price of Share-Yahoo Finance, for 1035 days, covering the period from 21st March 2011 to 20th March 2015. SBI is the two hundred years old largest public sector commercial bank with an assets size over rupees thirteen trillion. SBI occupies 22% share in Indian banking market. The Govt. of India is the largest share holders of SBI and has 58.6% ownership.

RESULT AND DISCUSSION

Derivation of three state transition probability matrices

From the data it is clear that the next day closing price of share of the bank is either increase, decrease or remains same. These three conditions are taken as the three states of transition probability matrix of Markov chain. If the closing price of t^{th} day is greater than the previous day i.e. $(t\text{-}1)^{th}$ day then it is described as **up** (U), if the closing price of t^{th} day is less than $(t\text{-}1)^{th}$ day then it is taken as **down** (D) and the price is same for t^{th} and $(t\text{-}1)^{th}$ day then it is taken as **remain same** (S). To determine the transition probability matrix the number of transition from one state to another state are calculated from the raw data. The movement of share price pattern from state **up** (U) to state **down** (D) is denoted by (UD).

Here 1035 trading days of share are considered and the number of observations for share price up, down and remain same have been found as 488, 515 and 32 respectively. Since the last trading day is recorded as down and there is no information regarding next day transition, the total number of down should be recorded as (515-1)= 514. The transition probability p_{UU} =250/488=0.5123 is the probability of transition from state **up** to another state **up** in the next trial and p_{UD}= 220/488=0.4508 is the probability of transition from state **up** to state **down**. The transition matrix for SBI share under the period of study is,

$$\mathbf{P_{SBI}} = \begin{array}{c} \\ U \\ D \\ S \end{array} \begin{array}{c} \begin{array}{ccc} U & D & S \end{array} \\ \begin{bmatrix} 0.5123 & 0.4508 & 0.0369 \\ 0.4300 & 0.5467 & 0.0233 \\ 0.4688 & 0.4375 & 0.0937 \end{bmatrix} \end{array}$$

The row sum of this matrix is one and all the entries non negative.

Initial state vector

In this study the three different states of closing price is considered which are **up**, **down** and **remain same**. The initial state vector gives the probability of the three different states. If the state vector is denoted by ®$^{(0)}$ = (π_1, π_2, π_3) then π_1, π_2

and π_3 gives the probability of share up, down and remain same as

π_1 =487/1035 = 0.4705
π_2 =515/1035=0.4979 and π_3 =33/1035=0.0319. Thus the initial state vector for SBI share is

$$®^{(0)} = [0.4705 \quad 0.4979 \quad 0.0319]$$

Calculating state probabilities for forecasting the next day share price

By applying initial state vector and transition probability matrix, it is possible to find out the state probabilities of various closing day in future. The state probabilities of closing price of share for SBI for 1036th day will be

$$®^{(1)} = ®^{(0)} * \mathbf{P_{SBI}} = [0.4705 \quad 0.4979 \quad 0.0319]* \begin{bmatrix} 0.5123 & 0.4508 & 0.0369 \\ 0.4300 & 0.5467 & 0.0233 \\ 0.4688 & 0.4375 & 0.0937 \end{bmatrix} = [0.4700 \quad 0.4981 \quad 0.0319]$$

Which indicate that in the 1036th day the state down has maximum probability and it can be predicted that share price of SBI will decrease in this day with probability 0.4981. Similarly the state probabilities of closing price of share for SBI for 1037th day will be

$$®^{(2)} = ®^{(1)} * \mathbf{P_{SBI}} = [0.4699 \quad 0.4981 \quad 0.0319]$$

Thus it can be said that there is a possibility of share price **up** with probability 0.4699, **down** with probability 0.4981 and **remain same** with probability 0.0319.
These predictions are same with the actual data.

Long term behaviour of Stock Price

The long term behaviour of share price can be determined by the n-step transition probability matrix. The n-step matrix $\mathbf{P}^{(n)}$ shows the behaviour of share price n-step later. If the number of steps increases then the $\mathbf{P}^{(n)}$ converges to limiting transition matrix $\mathbf{P}^{\infty)}$**,** where each row of the matrix is identical and it is said that the chain has attained steady state or state of equilibrium. The steady state matrix provides the probability of share price increase, decrease and remains same in the future. In other words, the nth power transition probability matrix will provide the probability that share price will be in a particular state in n days, given that it is currently in some specified state. To examine the long term behaviour of shares, the higher order transition probability matrix for the bank is calculated with the help of the statistical software MATLAB as follows.

The higher order transition matrices for SBI

$$\mathbf{P}^{(2)}_{\mathbf{SBI}} = \begin{bmatrix} 0.4736 & 0.4935 & 0.0329 \\ 0.4663 & 0.5029 & 0.0308 \\ 0.4722 & 0.4915 & 0.0363 \end{bmatrix}$$

$$\mathbf{P}^{(5)}_{\mathbf{SBI}} = \begin{bmatrix} 0.4699 & 0.4981 & 0.0319 \\ 0.4699 & 0.4982 & 0.0319 \\ 0.4699 & 0.4981 & 0.0363 \end{bmatrix}$$

$$\mathbf{P}^{(6)}_{\mathbf{SBI}} = \begin{bmatrix} 0.4699 & 0.4981 & 0.0319 \\ 0.4699 & 0.4981 & 0.0319 \\ 0.4699 & 0.4981 & 0.0319 \end{bmatrix}$$

$$\mathbf{P}^{(7)}_{\mathbf{SBI}} = \mathbf{P}^{(8)}_{\mathbf{SBI}} = \mathbf{P}^{(9)}_{\mathbf{SBI}} = \dots = \begin{bmatrix} 0.4699 & 0.4981 & 0.0319 \\ 0.4699 & 0.4981 & 0.0319 \\ 0.4699 & 0.4981 & 0.0319 \end{bmatrix}$$

From the higher order transition matrix of SBI, it is noticed that after a period of six trading days, the matrix approaches to the state of equilibrium. If the number of steps is increased for the matrix, the results remain invariant.

Thus, the following conclusions may be drown for SBI share from the matrix $\mathbf{P}^{(6)}_{\mathbf{SBI}}$

The probability that the share prices increase in near future, irrespective of its initial states **up**, **down** or **remain same** is 0.4699.

The probability that the share prices decrease in near future, irrespective of its initial states **up**, **down** or **remain same** is 0.4981.

The probability that the share prices remain same in near future, irrespective of its initial states **up**, **down** or **remain same** is 0.0319.

Thus the Markov chain analysis may guide the investors of the banks towards their long term investments.

Expected Number of visits

Here an attempt has been made to find out the expected number of visits, the share prices make to a particular state from another state in different steps.

For SBI share, the number of visits the chain makes in a four days is given by the following matrix.

$$\mathbf{V}_{\mathrm{SBI}}^{(4)} = \begin{array}{c} \\ U \\ D \\ S \end{array} \begin{array}{c} \begin{array}{ccc} U & D & S \end{array} \\ \begin{bmatrix} 2.4561 & 1.4420 & 0.1018 \\ 1.3659 & 2.5482 & 0.0859 \\ 1.4113 & 1.4265 & 1.1622 \end{bmatrix} \end{array}$$

From the matrix $\mathbf{V_{SBI}}^{(4)}$ it may be concluded that if the closing price of share for SBI in day one is in the state **up** then the expected number of visits the chain makes to the state **up** in four days is 2.4561, to the state **down** is 1.4420 and to the state **remain same** is 0.1018.

Expected first reaching time

Let $n_{\mathbf{UD}}$ denotes the number of steps before the chain reaches the state **down** (D) for the first time, starting from the state **up** (**U**). This is interpreted as the chains first reaching time from state **up** to state **down**. We are interested to find the expected first reaching time i.e. E (n_{ij}) for different stats. For a particular state j in a finite irreducible chain all **E (**n_{ij}**)**'s must be finite. These **E (**n_{ij}**)**'s can be calculated by using matrix form which is given by

$\mathbf{N = E + P (N–N_d)}$ where $\mathbf{N= [E (n_{ij})], N_d}$ is the matrix N with all diagonal elements replaced by zeros and **E** is the (N×N) matrix in which all elements are equal to one. The expected first reaching time matrix for different states of SBI share is

$$\mathbf{N_{SBI}} = \begin{bmatrix} \mathbf{E}(\mathbf{n}_{UU}) & \mathbf{E}(\mathbf{n}_{UD}) & \mathbf{E}(\mathbf{n}_{US}) \\ \mathbf{E}(\mathbf{n}_{DU}) & \mathbf{E}(\mathbf{n}_{DD}) & \mathbf{E}(\mathbf{n}_{DS}) \\ \mathbf{E}(\mathbf{n}_{SU}) & \mathbf{E}(\mathbf{n}_{SD}) & \mathbf{E}(\mathbf{n}_{SS}) \end{bmatrix} =$$

$$\begin{bmatrix} 2.1280 & 2.2208 & 33.2019 \\ 2.3203 & 2.0074 & 33.7013 \\ 2.2235 & 2.2522 & 31.3093 \end{bmatrix}$$

From the above first reaching time matrix $\mathbf{N_{SBI}}$, it is clear that the first reaching times to any given state say **up,** from each possible initial states up, down and remain same are approximately equal. If the closing value of share price of SBI is in the state up (U) in day one, then it can expect to reach the state up (U) for the first time after two days. If the closing value of share price either in the state down (D) or in the state remain same (S) it will take two days on average to reach the state up (U). That is it does not depend on its initial state. If a share price of SBI has either in the state up (U) or down (D) it will take about 33 days on average before it experience the state of remain same (S) for the first time. If it is in the state remain same then it will take approximately 31 days to reach the state remain same.

Expected Return time

Expected return time to a particular state reflects another aspect of share price behaviour. The expected return time to same state can be directly calculated from visiting rate as well as from steady state matrix. For a finite irreducible chain the expected return time is the reciprocal of the steady state probabilities. For SBI share the expected return time to the state **up**, starting from same state **up** is **E** (n_{UU}) = 1/0.4699=2.128. Similarly the expected return time to the state **down**, starting from the state **down** is **E** (n_{DD}) = 2.007 and remain same is **E** (n_{SS}) =31.347. Now from the above calculation it can be concluded that the chain should visit the state **up,** on average in two days, state down in two days and the state remain same on average in 31 days. The periods of expected return time for different states are identical to the periods derived from the expected first reaching time.

CONCLUSIONS

Stock market prediction is not a simple task because it is highly influenced by many factors such as global and regional economic conditions, the different policies undertaken by government, political and social situations, the investor's faith in the market etc. To apply Markov chain model, it is assumed that the stock market is influenced by random factors only and the ups and down of stock price in a particular day depends only on the previous day's closing price. Here the Markov chain model is used to predict the behaviour of stock price of SBI. The Markov chain model expressed the behaviour of stock price in a probabilistic way. It is not possible to get the accurate result of forecasting in absolute state.

The transition probability matrices and initial state vectors give the picture of the next day share price for both the banks. The n-step transition probability matrices provide the long term behaviour of share price. The results derived from steady state probability matrices show that the SBI share price increases in future with probability 0.4699. The share price will decrease with probability 0.4981 and the probabilities for share price remain same is derived as 0.0319. The expected numbers of visits to three different steps from any one of the initial states made by the chain are calculated. For SBI, 2.4561 is the expected number of visits the chain made to the state up from the state up in four days. It is seen that, the expected first reaching time to any given state from the three states are approximately equal. If the SBI share price is either in the state up, down, or the state remain same then it will reach the state up or down after two days. After 31 days it will in the state remain same on average if the chain initially in the state remain same and takes approximately 33 days if it is in the state up or down. Whether the most of results for share price up, down and remain same are expressed in probabilities but the results have some economic significance. These may help the future investors and share holders for the bank.

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