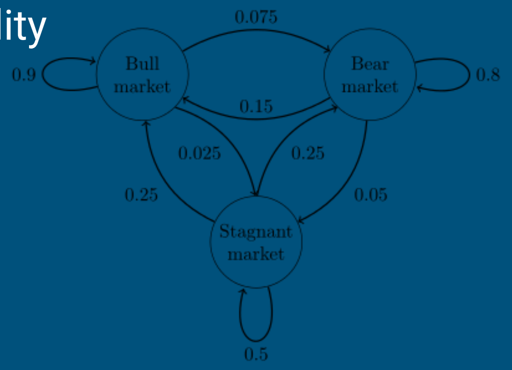
Exploring Markov Chains in Stock Market Trends

Aim of the project

To analyze and predict the future behavior of the stock market using Markov Analysis

We applied a Markov chain model for the analysis of the stock market movement and forecasting its share prices to get maximum profit on their investments and defend the features of randomness and disorder of stock market volatility



What is stock market?

The stock exchange is a legal framework where an individual or group of individual can buy and sell such shares in a systematic way.

Importance of stock market

The fluctuation in stock market can have a profound influence on individuals and the entire economy as well.

That is why it is most essential to come up with statistical models and their analysis.

Stock market is one of the best alternative for various business houses and companies for further expansion or settling up a new business venture

How the stock prices fluctuate?

A competent stock market is considered to have such integral characteristics in which the price of shares should randomly fluctuate.

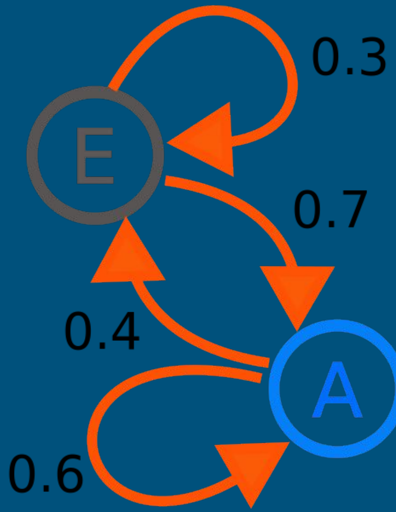
The random fluctuation of price of shares causes the uniform distribution of market information. The historic randomness and volatility in the share prices are obtained using a series of past market prices.

This inherent stochastic behavior of stock market makes the prediction of possible states of the market using previous information.

Markov Analysis

Markov analysis is a method for forecasting the value of a variable whose anticipated value is only impacted by its present state.

The key benefits of Markov analysis are its simplicity and accuracy in out-of-sample predictions.



Markov process

Any random process that follows Markov property is called a *Markov process*.

Let $\{X\ t\ ,\ t \geq 0\}$ is a sequence of events, then

$P[Xt{+}1 = j|Xt = i, Xt{-}1 = i{-}1, \ldots, X1 = 1, X0 = 0] = P[Xt{+}1 = j\ |Xt = i] = aij \geq 0,$

where $\sum aij = 1$

Markov Chain to predict Stock Market

The purpose of our model will be to predict the future state, the only requirement would be to know the current state.

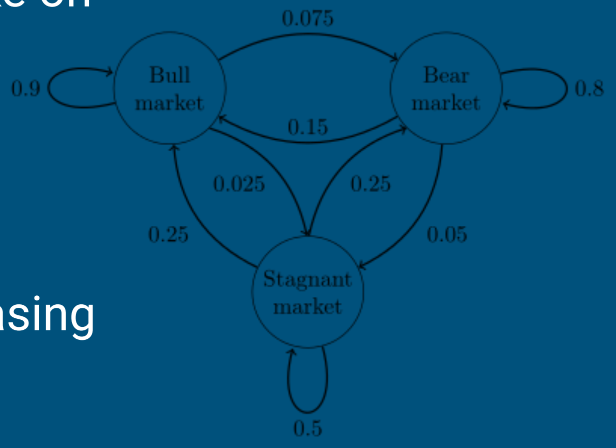
There are three measures to construct a Markov chain:

- **States:** All the states (occurrences) within the state-space ‘s’ of the dynamical system
- **The initial state distribution:** The initial probability distribution of the starting state. It is denoted as ‘q’
- **State transition probabilities:** transition probability of moving from one state to another. It is denoted as ‘P’

The Stock Markets Movement as a Markov Chain Model

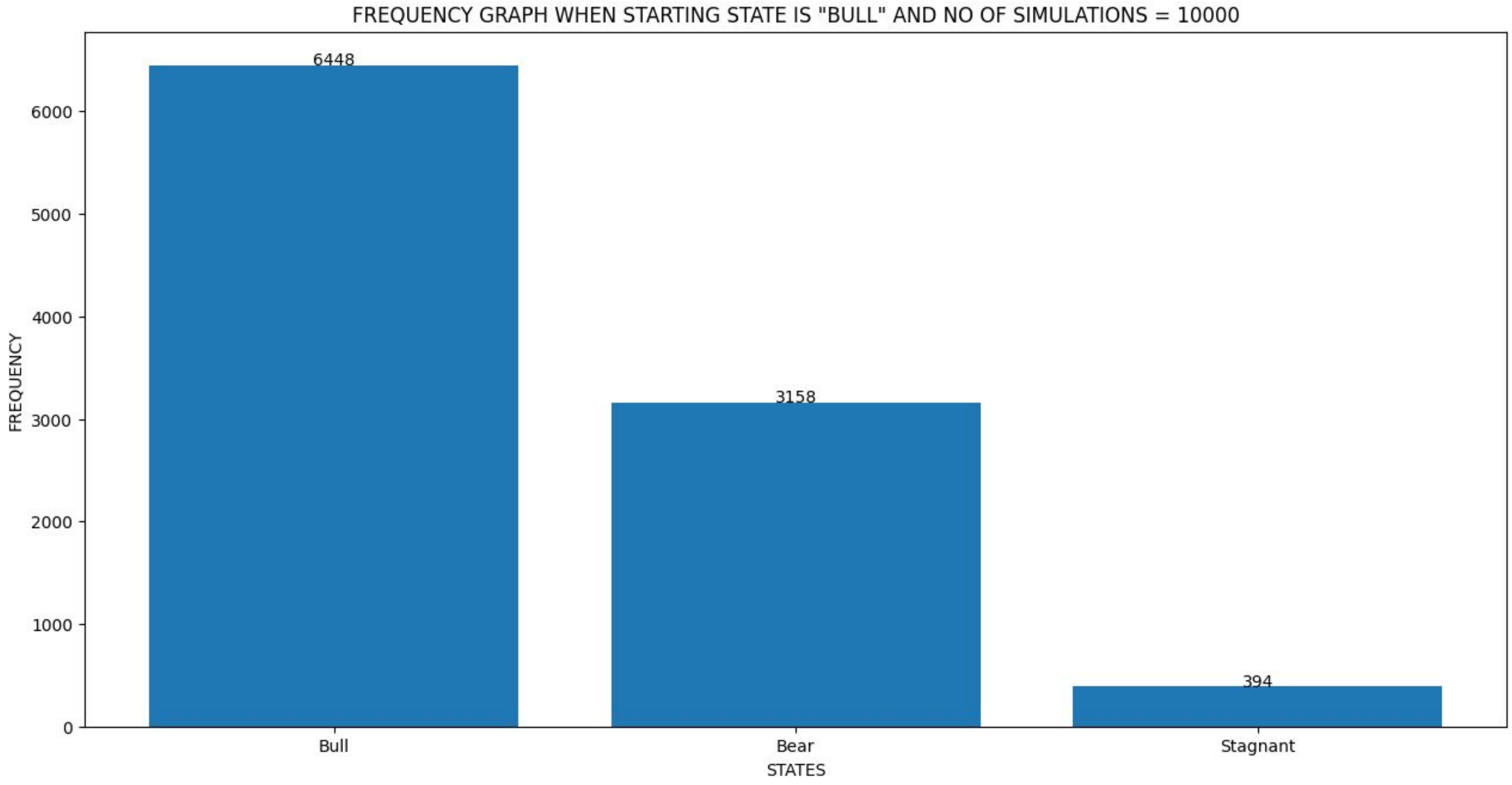
We can identify that a stock markets movement can take on three states (the state-space):

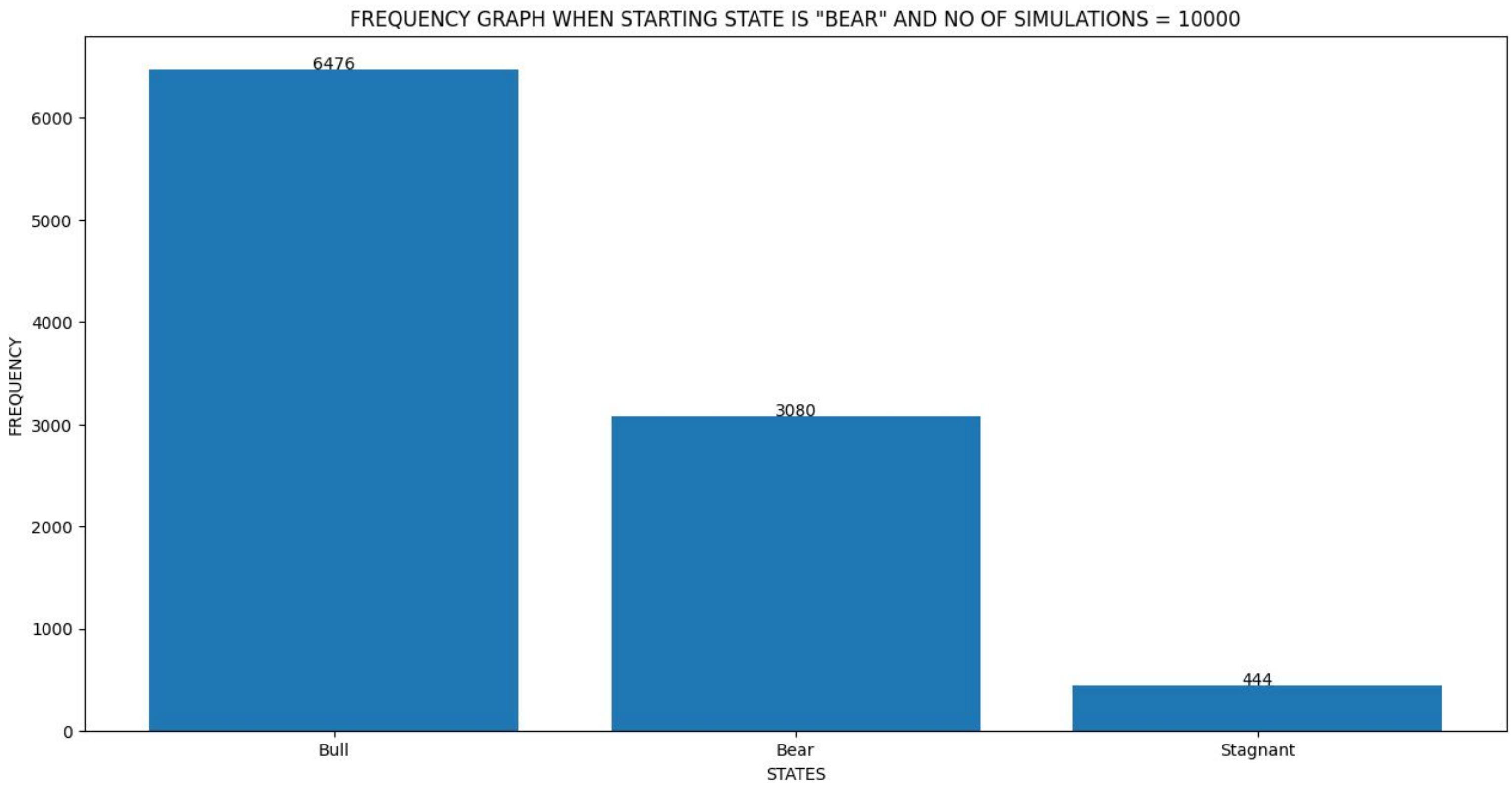
- **Bull:** the price is increasing
- **Bear:** the price is decreasing
- **Stagnant:** there is no change in price, neither increasing nor decreasing

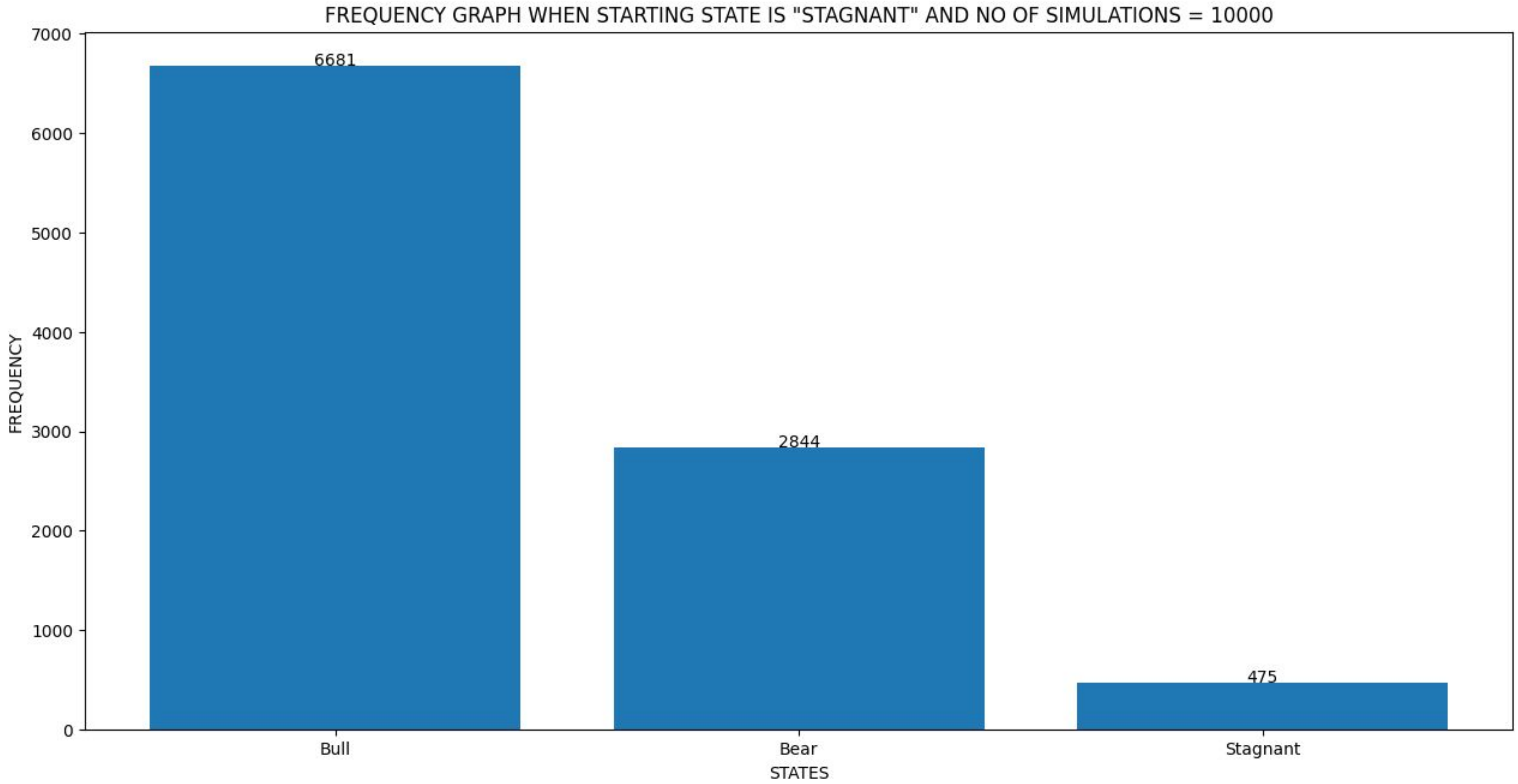


Probability Transition Matrix

	BULL(0)	BEAR(1)	STAGNANT(2)
BULL(0)	0.9	0.075	0.025
BEAR(1)	0.15	0.8	0.05
STAGNANT(2)	0.5	0.25	0.25


FREQUENCY GRAPH WHEN STARTING STATE IS "BULL" AND NO OF SIMULATIONS = 10000
6448
3158
394
0
1000
2000
3000
4000
5000
6000
FREQUENCY
Bull
Bear
Stagnant
STATES


FREQUENCY GRAPH WHEN STARTING STATE IS "BEAR" AND NO OF SIMULATIONS = 10000
FREQUENCY
STATES
6476
3080
444
Bull
Bear
Stagnant
0
1000
2000
3000
4000
5000
6000



FREQUENCY GRAPH WHEN STARTING STATE IS "STAGNANT" AND NO OF SIMULATIONS = 10000
7000
6000
5000
4000
3000
2000
1000
0
FREQUENCY
6681
2844
475
Bull
Bear
Stagnant
STATES

Analysis for a particular share value

In this analysis we will consider the share can give 5 types of returns :

Hg: When $(xn - xn{-}1) > +10$, the process is in the state of High gain.

Lg: When $+1 < (xn - xn{-}1) < +10$, the process is in the state of Low gain.

Nc: When $-1 < (xn - xn{-}1) < +1$, the process is in the state of No change.

Ll: When $-10 < (xn - xn{-}1) < -1$, the process is in the state of Low loss.

Hl: When $(xn - xn{-}1) < -10$, the process is in the state of High loss.

where xn is current and $xn{-}1$ is the previous closing share prices

Understanding More With an Example

State Space = S = { High Gain, Low Gain, No Change, Low Loss, High Loss }

However, there are various statistical methods to study such phenomena like; Moving average, Regression analysis, Markov chain model, Hidden Markov processes, Weighted Markov chain etc. to forecast the stock market using past information. In order to analyze and predict the stock market behavior, the Markov chain model has been used by many researchers in different time and it is within our scope of study.

Dataset Description / Count Matrix

	HG	LG	Nc	LL	HL	Total
HG	88	26	9	20	73	216
LG	25	7	2	3	20	57
NC	8	2	0	1	4	15
LL	14	3	1	4	25	47
HL	82	19	3	18	59	181

Transition frequency Table is used to determine the Transition probability matrix.

Derivation of Probability Matrix

The above Frequency Transition Matrix/ Count Matrix show all the Cij. Then Pij is calculated by the following formula:

Probability of transition from i to j i.e P_{ij} *is calculated in the following way*

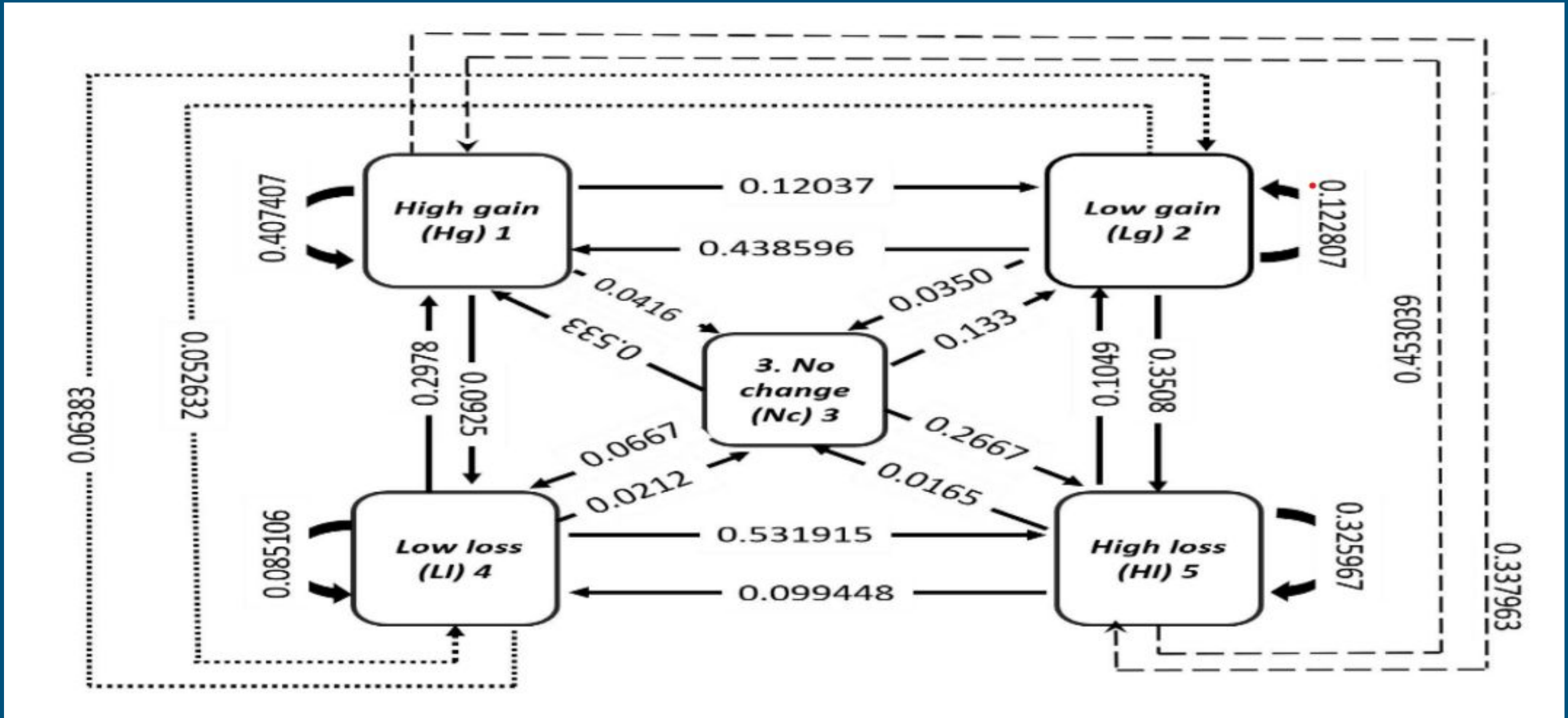
$$P_{ij} = \frac{C_{ij}}{\sum_{k=1}^{22} C_{ik}}$$

where, C_{ij} *is the count of transition from i to j*

Probability Transition Matrix Table for the share

	High Gain (0)	Low Gain (1)	No Change (2)	Low Loss (3)	High Loss (4)
High Gain(0)	0.407407	0.120370	0.041667	0.092593	0.337963
Low Gain(1)	0.438596	0.122807	0.035088	0.052632	0.350877
No Change(2)	0.533333	0.133333	0	0.066667	0.266667
Low Loss(3)	0.297872	0.063830	0.021277	0.085106	0.531915
High Loss(4)	0.453039	0.104972	0.016575	0.099448	0.325966

Probability Transition Diagram



Probability Distribution of nth day (step)

$$\Pi(n)=\Pi(0)*P^n$$

where, $\Pi(0)$= initial distribution

P= transition probability matrix

$\Pi(n)$ = probability distribution of nth day

Computation of state probabilities for forecasting the share price

Starting State = Low Gain
Probability of States after 1 day, 5 days, 10 days

$\Pi(0) = [0,1,0,0,0]$

After Simulating Using Code in R

We get the values of $\Pi(n)$

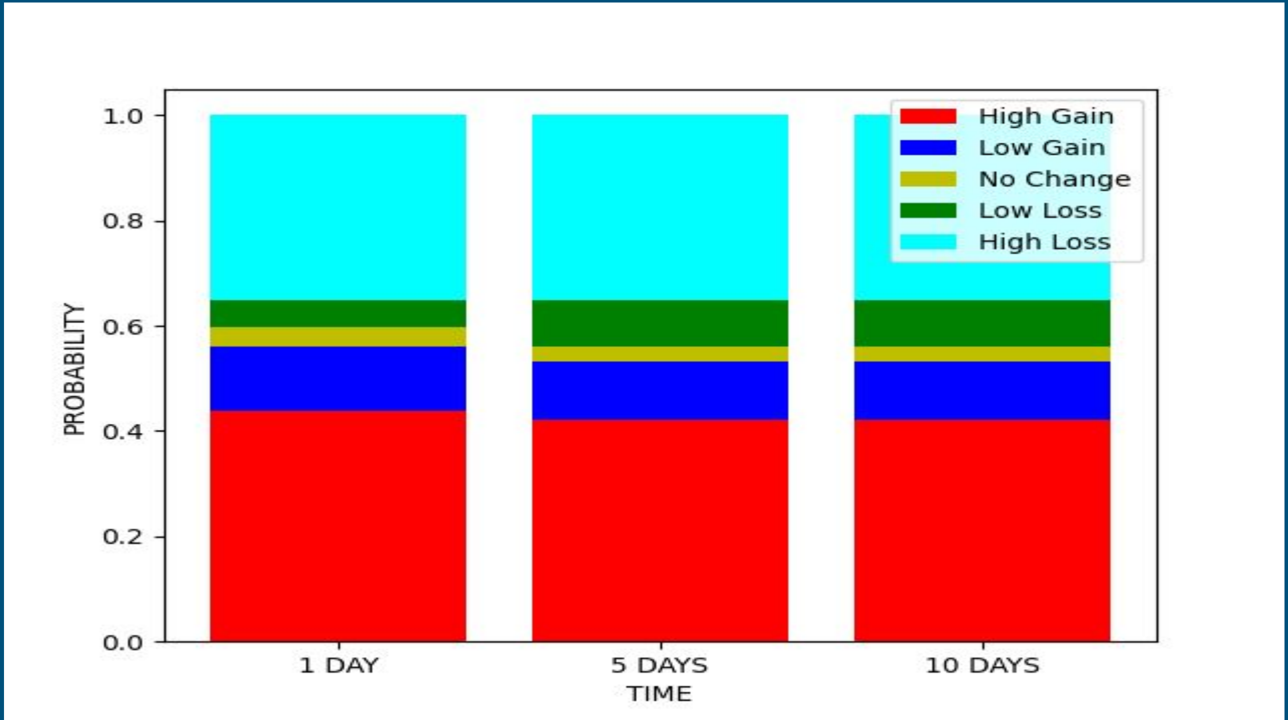
for n = 1,5,10

```
[1] "π(1)"
         [,1]     [,2]     [,3]     [,4]     [,5]
[1,] 0.438596 0.122807 0.035088 0.052632 0.350877

[1] "π(5)"
          [,1]      [,2]       [,3]       [,4]      [,5]
[1,] 0.4207454 0.1105817 0.02911743 0.08915326 0.3504022

[1] "π(10)"
          [,1]      [,2]       [,3]       [,4]      [,5]
[1,] 0.4207465 0.1105807 0.02911615 0.08915374 0.3504029
```

Graph For Π(n), Initial State = Low Gain



Starting State = High Loss
Probability of States after 1 day, 5 days, 10 days

$\Pi(0) = [0,0,0,0,1]$

After Simulating Using Code in R

We get the values of $\Pi(n)$

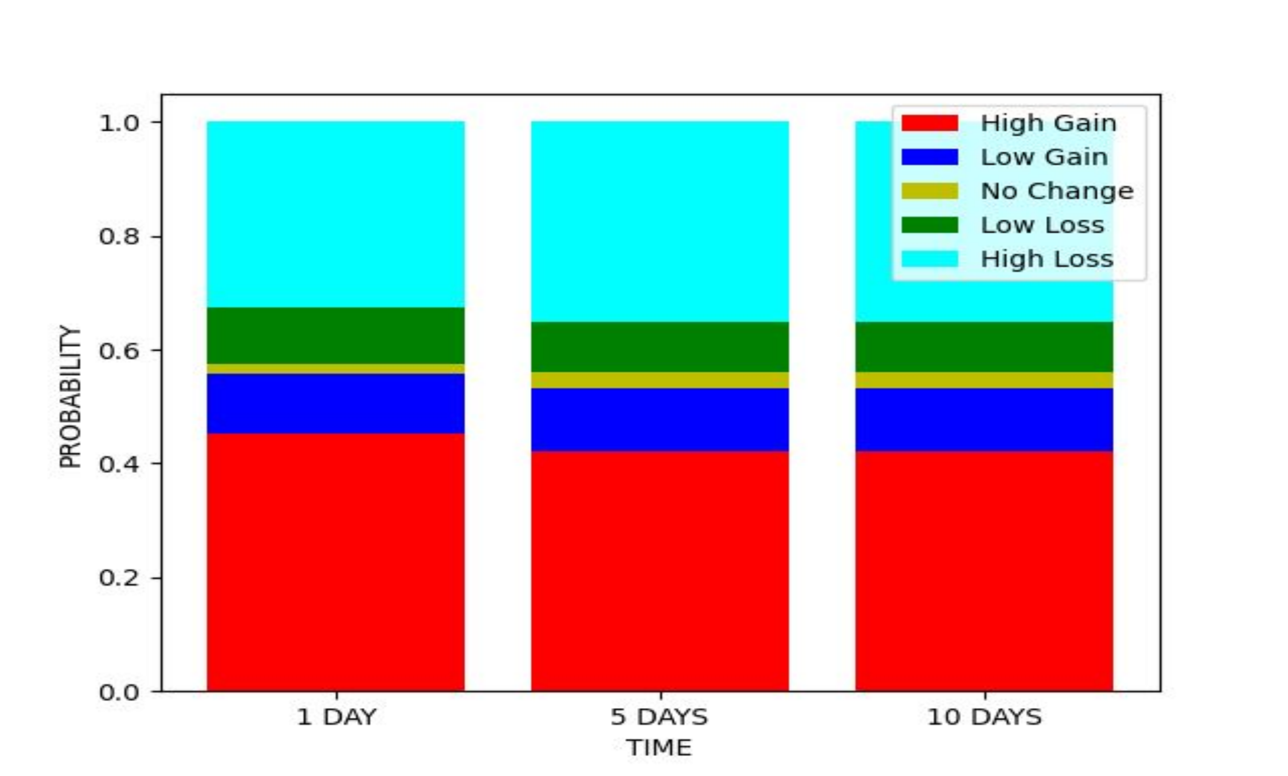
for n = 1,5,10

```
[1] "π(1)"
          [,1]     [,2]     [,3]     [,4]     [,5]
[1,] 0.453039 0.104972 0.016575 0.099448 0.325966

[1] "π(5)"
          [,1]      [,2]       [,3]       [,4]      [,5]
[1,] 0.4207472 0.1105803 0.02911553 0.08915366 0.3504033

[1] "π(10)"
          [,1]      [,2]       [,3]       [,4]      [,5]
[1,] 0.4207465 0.1105807 0.02911615 0.08915374 0.3504029
```

Graph For Π(n), Initial State = High Loss



Stationary or stable probability distribution of Markov chain

The stationary property of Markov process claim that if transition steps increase, then the transition probability of reaching to state *j* from state *i* will converge to some constant value.

$\lim P_{ij}(n) = \lim \pi(n) = \pi_j$ (n tends to ∞)

Stationary Probability Distribution of Share Prices

Long run behavior of share price is obtained by determining the higher-order TPMs reaching the stationary probability distribution of share prices by using R software.

We see that stationary condition is reached after 6th state

I.e $A6=A7=A8=...=An$.

Stationary Matrix Table for the share

	High Gain (0)	Low Gain (1)	No Change (2)	Low Loss (3)	High Loss (4)
High Gain(0)	0.420747	0.110581	0.029116	0.089153	0.350403
Low Gain(1)	0.420747	0.110581	0.029116	0.089153	0.350403
No Change(2)	0.420747	0.110581	0.029116	0.089153	0.350403
Low Loss(3)	0.420747	0.110581	0.029116	0.089153	0.350403
High Loss(4)	0.420747	0.110581	0.029116	0.089153	0.350403

Application of stationary state

The stationary state property of Markov Chain is used to analyse movement and predict long run behaviour of the system.

Even though we started from 2 different initial state i.e from high gain and low loss on calculating Π^{10}, it shows a similar probabilities in both the cases. So, it shows that the stationary state doesn't depend on the initial state.

Applications

1.To study the long run behavior of market index.

2. To determine the expected number of visits to a particular state.

3. To find out the expected first return time of various states.

4. By applying MC model, it is easy for us to obtain the information not only about whether or not the stock price will increase in the future, but can also forecast how long it will keep on increasing.

5.Markov Chain model explains the behavior and movement of share price trend in probability measures. The interpretation of TPM reveals that the probability of the state Nc is very less demonstrating the volatility of the stock market.

Disadvantages of Stock market Analysis

1. The model entirely works on probability and can sometimes get wrong.
2. Stock market can wipe our entire money and investments.
3. Insider Trading doesn’t follow this matrix and hence influence the prices.
4. External factors such a government policies can influence the prices.

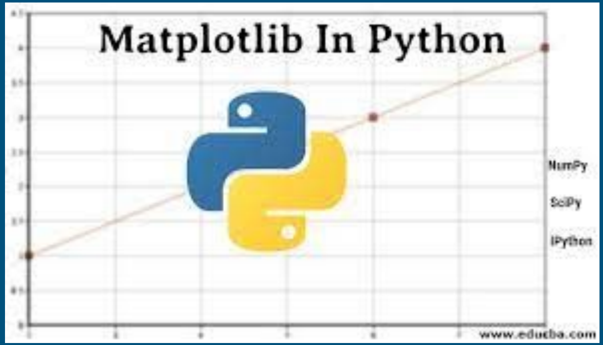
Tools used for the analysis

- Python

  Matplotlib

  Numpy

- R Language



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Thank You !