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**BANA 7030**

**Simulation Modeling and Methods**

**Monte Carlo Simulation of Stock Price**

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## **Introduction**

The financial market is a prime example of a complex and stochastic system which means it is composed of several different components which all operate on a limited amount of information, or in other words a high level of uncertainty and randomness. Numerous factors such as stock market prices, interest rate for loans, any major political event, affect one another and that makes the financial market a very complex system. Therefore, it becomes very crucial for investors to be able to model the probability of possible outcomes of financial investments and financing decisions in order to produce fruitful and productive investments and Monte Carlo simulation appears to possibly turn into an amazing asset that can grow our capacities to do likewise.

This study investigates how Monte Carlo simulations of random walks can be used to model the future stock prices. The implemented method uses a mathematical model called Geometric Brownian Motion (GBM) in order to simulate stock prices. 7-year stock price data of Reliance Industries Limited was used as a data set for the simulations to conduct study for 1 month, 3 months, 6 months, and 12 months period. Probability factor for predicted stock price to be greater than the actual price was then calculated from the simulations. The two fundamental parameters which determine the outcome of the simulations are the mean return of a stock and the standard deviation of historical returns.

## **Data Selection**

The data consists of Reliance Industries Limited stock data on National Stock Exchange of India Limited. The data sets were downloaded from Yahoo Finance website and consists of 6 years, 2012-01-01 to 2017-12-31 of stock prices which were used to calculate statistical values. The last year of stock price data was used as a reference for comparing the simulated and actual prices. Stock price chart for the same is shown below –

## **Problem Approach**

Following steps were followed to generate simulations for future stock prices –

### **Mean and Standard Deviation**

The log return **(ln(closing\_price/opening\_price))** of stock prices was calculated for each day of trading. From the calculated data, mean value for the return of stock and the standard deviation (sigma) of historical returns ware then deduced.

### **Geometric Brownian Motion (GBM)**

The idea behind simulating future stock prices is to generate thousands of random walks and each random walk is assumed to follow a Geometric Brownian Motion (GBM) which is a continuous-time stochastic process in which the logarithm of the randomly varying quantity follows a Brownian motion with drift and shock value as defined below –

**Drift = (mean - (sigma^2)/2)\*dt**

**Shock = sigma\*(dt^0.5)\*N(0,1)**

Following values were calculated using the above formulas –

|  |  |
| --- | --- |
| Average Daily Return (mean) | 0.0006600 |
| Standard Deviation (sigma) | 0.0159224 |
| Time difference (dt - day) | 1 |
| Drift | 0.0005332 |
| Shock | 0.0004848 |

### **Stock Price Calculation**

For each day 10000 simulations were generated and in each step of the Monte Carlo simulation, the next day stock price was calculated using the below formula and above values-

**St = S t-1\*exp((mean - (sigma^2)/2)\*dt + sigma\*(dt^0.5)\*N(0,1)**

## **Data Simulations Results**

Below chart shows the actual distribution of stock price for simulated time period and will be used to compare the simulation results.

### **1 - Month prediction interval**

It can be observed from the above plot that **none of the values** happened to fall below $750, and above $1200. As compared with the actual plot values, it can be said that the prediction values have been **overestimated for some of the trading days** as the actual values ranges between $800 to $1000.

### **3 - Months prediction interval**

It can be observed from the above plot that **none of the values** happened to fall below $700, and above $1400. As compared with the actual plot values, it can be said that some of the predicted values have been **largely overestimated** as the actual values ranges between $800 to $1000. It can also be observed that this chart is wigglier from previous and some of the predicted values have gone beyond the normal values.

### **6 - Months prediction interval**

It can be observed from the above plot that **most of the values** happened to fall between $600 and $1600. As compared with the actual plot values, it can be said that some of the predicted values have been **largely overestimated as well as underestimated** as the actual values ranges between $800 to $1200. It can also be observed that this chart is wigglier from previous ones.

### **12 - Months prediction interval**

It can be observed from the above plot that **some of the values** are touching the $2000 mark and going as below as $500. As compared with the actual plot values, it can be said that some of the predicted values have been **largely overestimated as well as underestimated** as the actual values ranges between $600 to $1400.

### **Average Prediction Value Chart**

It can be observed from the above chart that for most of the trading days, the average of simulated values is very close to the actual values except for the part where sudden jump has occurred in the actual values where average value is very less. This also concludes that the overestimated and underestimated values (as identified in last parts) are very less in number since average is nearby the actual values. This can also be verified from the below distribution plots.

### **Predicted Stock Value Distribution**

Below plots shows the distribution of simulated values at the end of each 1 month, 3 months, 6 months, and 12 months period. It can be observed that all are following the normal distribution and most of the values are somewhere around the actual values.

|  |  |
| --- | --- |
|  |  |
|  |  |

### **Prediction Probability**

It was deduced from the simulated data that for **around 34 percent** of total trading days (245 days) in the reference year, 50 percent of predicted stock price values at any day were greater than the actual value at that day.

## **Conclusion**

Through this work, we studied how to model the probability of future stock returns using Monte Carlo simulations with Geometric Brownian Motion as underlying stock price model. The accuracy of such approach may however not be good enough for most investors who want to analyse trends. More research should be conducted to conclude whether the Monte Carlo method can be used for business purposes.

## **References**

[1] Monte Carlo simulation with GBM [https://www.investopedia.com/articles/07/montecarlo.asp]

[2] Yahoo Finance for stock price data [https://in.finance.yahoo.com/quote/RELIANCE.NS/history/]

[3] Lognormal stock prices

[https://stats.stackexchange.com/questions/125761/why-stock-prices-are-lognormal-but-stock-returns-are-normal]

[4] Modelling the probability of future stock returns

[http://www.diva-portal.se/smash/get/diva2:1214365/FULLTEXT01.pdf]

## **Appendix**

1. Monte Carlo simulation results

|  |  |  |  |
| --- | --- | --- | --- |
| **Date** | **Actual Opening Stock Price** | **Average Predicted Opening Stock Price** | **Probability that predicted price is less than actual value** |
| 1/1/2018 | 922.700 | 922.700 | 0 |
| 1/2/2018 | 913.000 | 923.217 | 0.7569 |
| 1/3/2018 | 925.000 | 923.937 | 0.4701 |
| 1/4/2018 | 918.150 | 924.718 | 0.5918 |
| 1/5/2018 | 921.800 | 925.118 | 0.5367 |
| 1/8/2018 | 926.100 | 925.802 | 0.4909 |
| 1/9/2018 | 928.150 | 926.160 | 0.4671 |
| 1/10/2018 | 943.000 | 926.698 | 0.331 |
| 1/11/2018 | 941.800 | 927.544 | 0.361 |
| 1/12/2018 | 943.000 | 928.078 | 0.3582 |
| 1/15/2018 | 950.000 | 928.796 | 0.3193 |
| 1/16/2018 | 947.700 | 929.525 | 0.3503 |
| 1/17/2018 | 926.000 | 930.304 | 0.5261 |
| 1/18/2018 | 929.000 | 930.929 | 0.505 |
| 1/19/2018 | 923.000 | 931.895 | 0.5539 |
| 1/22/2018 | 948.000 | 932.716 | 0.3888 |
| 1/23/2018 | 975.000 | 933.053 | 0.2362 |
| 1/24/2018 | 981.750 | 933.921 | 0.2132 |
| 1/25/2018 | 967.900 | 934.363 | 0.293 |
| 1/29/2018 | 966.200 | 934.912 | 0.3092 |
| 1/30/2018 | 965.800 | 935.523 | 0.3187 |
| 1/31/2018 | 950.000 | 936.360 | 0.4113 |
| 2/1/2018 | 963.250 | 936.856 | 0.3473 |
| 2/2/2018 | 935.000 | 937.547 | 0.4976 |
| 2/5/2018 | 894.000 | 937.968 | 0.7197 |
| 2/6/2018 | 877.000 | 938.430 | 0.7885 |
| 2/7/2018 | 902.550 | 939.237 | 0.6765 |
| 2/8/2018 | 897.900 | 940.035 | 0.6951 |
| 2/9/2018 | 889.000 | 940.611 | 0.7337 |
| 2/12/2018 | 903.000 | 941.053 | 0.6715 |
| 2/14/2018 | 923.000 | 941.775 | 0.5776 |
| 2/15/2018 | 937.650 | 942.176 | 0.5076 |
| 2/16/2018 | 939.600 | 942.908 | 0.503 |
| 2/19/2018 | 921.000 | 943.523 | 0.5879 |
| 2/20/2018 | 929.000 | 944.485 | 0.5492 |
| 2/21/2018 | 930.000 | 945.064 | 0.5507 |
| 2/22/2018 | 922.000 | 945.560 | 0.5843 |
| 2/23/2018 | 925.400 | 946.396 | 0.5682 |
| 2/26/2018 | 939.000 | 947.074 | 0.5164 |
| 2/27/2018 | 939.000 | 947.463 | 0.5164 |
| 2/28/2018 | 945.950 | 948.148 | 0.4916 |
| 3/1/2018 | 949.750 | 948.918 | 0.477 |
| 3/5/2018 | 943.000 | 949.316 | 0.5031 |
| 3/6/2018 | 929.000 | 949.996 | 0.5657 |
| 3/7/2018 | 909.250 | 950.448 | 0.6476 |
| 3/8/2018 | 897.650 | 951.282 | 0.6893 |
| 3/9/2018 | 914.900 | 951.897 | 0.6232 |
| 3/12/2018 | 920.000 | 952.675 | 0.6052 |
| 3/13/2018 | 931.900 | 953.341 | 0.5622 |
| 3/14/2018 | 928.800 | 953.892 | 0.572 |
| 3/15/2018 | 925.000 | 954.615 | 0.5881 |
| 3/16/2018 | 909.000 | 955.075 | 0.6484 |
| 3/19/2018 | 901.000 | 955.745 | 0.6754 |
| 3/20/2018 | 893.300 | 956.441 | 0.7018 |
| 3/21/2018 | 894.850 | 957.162 | 0.6969 |
| 3/22/2018 | 896.000 | 957.793 | 0.6915 |
| 3/23/2018 | 890.600 | 958.238 | 0.7096 |
| 3/26/2018 | 893.950 | 958.819 | 0.697 |
| 3/27/2018 | 907.200 | 959.612 | 0.657 |
| 3/28/2018 | 895.800 | 960.041 | 0.6933 |
| 4/2/2018 | 893.000 | 960.472 | 0.7027 |
| 4/3/2018 | 891.000 | 961.197 | 0.7083 |
| 4/4/2018 | 904.700 | 961.831 | 0.665 |
| 4/5/2018 | 905.100 | 962.457 | 0.6641 |
| 4/6/2018 | 908.000 | 963.140 | 0.6557 |
| 4/9/2018 | 912.550 | 963.758 | 0.6408 |
| 4/10/2018 | 918.400 | 964.495 | 0.6206 |
| 4/11/2018 | 921.800 | 965.063 | 0.6072 |
| 4/12/2018 | 929.850 | 965.552 | 0.5813 |
| 4/13/2018 | 932.700 | 966.114 | 0.5758 |
| 4/16/2018 | 934.450 | 966.927 | 0.5701 |
| 4/17/2018 | 940.000 | 967.605 | 0.5555 |
| 4/18/2018 | 945.250 | 968.358 | 0.543 |
| 4/19/2018 | 939.100 | 968.829 | 0.562 |
| 4/20/2018 | 938.000 | 969.597 | 0.5661 |
| 4/23/2018 | 930.000 | 970.484 | 0.5955 |
| 4/24/2018 | 935.800 | 971.205 | 0.578 |
| 4/25/2018 | 973.650 | 972.049 | 0.4666 |
| 4/26/2018 | 973.000 | 972.936 | 0.472 |
| 4/27/2018 | 989.800 | 973.723 | 0.4252 |
| 4/30/2018 | 982.000 | 974.485 | 0.4498 |
| 5/2/2018 | 967.000 | 975.469 | 0.4923 |
| 5/3/2018 | 977.900 | 976.412 | 0.4653 |
| 5/4/2018 | 962.850 | 977.288 | 0.5111 |
| 5/7/2018 | 958.850 | 977.926 | 0.526 |
| 5/8/2018 | 977.500 | 978.364 | 0.4726 |
| 5/9/2018 | 965.900 | 978.948 | 0.5069 |
| 5/10/2018 | 980.000 | 979.540 | 0.464 |
| 5/11/2018 | 981.250 | 980.367 | 0.4638 |
| 5/14/2018 | 991.950 | 980.946 | 0.437 |
| 5/15/2018 | 983.050 | 981.632 | 0.4635 |
| 5/16/2018 | 974.000 | 982.146 | 0.4859 |
| 5/17/2018 | 959.350 | 982.729 | 0.5262 |
| 5/18/2018 | 945.600 | 983.469 | 0.5661 |
| 5/21/2018 | 930.750 | 984.421 | 0.6107 |
| 5/22/2018 | 933.150 | 985.326 | 0.6034 |
| 5/23/2018 | 926.000 | 985.919 | 0.6263 |
| 5/24/2018 | 914.000 | 986.762 | 0.6564 |
| 5/25/2018 | 916.000 | 987.483 | 0.654 |
| 5/28/2018 | 924.900 | 988.102 | 0.6304 |
| 5/29/2018 | 921.500 | 988.504 | 0.6393 |
| 5/30/2018 | 914.850 | 989.316 | 0.6555 |
| 5/31/2018 | 921.000 | 989.871 | 0.6371 |
| 6/1/2018 | 920.000 | 990.777 | 0.6409 |
| 6/4/2018 | 933.400 | 991.551 | 0.6114 |
| 6/5/2018 | 942.800 | 992.340 | 0.5863 |
| 6/6/2018 | 947.000 | 992.699 | 0.5734 |
| 6/7/2018 | 954.900 | 993.110 | 0.5545 |
| 6/8/2018 | 966.350 | 993.790 | 0.5272 |
| 6/11/2018 | 987.100 | 994.381 | 0.4787 |
| 6/12/2018 | 983.400 | 995.331 | 0.4898 |
| 6/13/2018 | 1000.000 | 995.645 | 0.4499 |
| 6/14/2018 | 997.450 | 996.099 | 0.4583 |
| 6/15/2018 | 1006.000 | 996.656 | 0.4383 |
| 6/18/2018 | 1008.800 | 997.174 | 0.433 |
| 6/19/2018 | 1013.900 | 997.810 | 0.4231 |
| 6/20/2018 | 996.000 | 998.283 | 0.4667 |
| 6/21/2018 | 1023.450 | 998.950 | 0.4022 |
| 6/22/2018 | 1028.400 | 999.636 | 0.3945 |
| 6/25/2018 | 1011.400 | 1000.475 | 0.4373 |
| 6/26/2018 | 1006.000 | 1000.861 | 0.4488 |
| 6/27/2018 | 978.500 | 1001.564 | 0.5102 |
| 6/28/2018 | 962.000 | 1002.056 | 0.5508 |
| 6/29/2018 | 949.100 | 1002.859 | 0.5837 |
| 7/2/2018 | 972.350 | 1003.534 | 0.5304 |
| 7/3/2018 | 965.000 | 1004.104 | 0.5467 |
| 7/4/2018 | 971.800 | 1004.786 | 0.5318 |
| 7/5/2018 | 997.000 | 1005.723 | 0.4765 |
| 7/6/2018 | 964.750 | 1006.235 | 0.5511 |
| 7/9/2018 | 987.100 | 1006.747 | 0.5024 |
| 7/10/2018 | 1002.750 | 1007.364 | 0.4699 |
| 7/11/2018 | 1025.000 | 1007.728 | 0.424 |
| 7/12/2018 | 1044.350 | 1008.186 | 0.3828 |
| 7/13/2018 | 1080.500 | 1008.838 | 0.3149 |
| 7/16/2018 | 1099.800 | 1009.546 | 0.2837 |
| 7/17/2018 | 1078.300 | 1010.281 | 0.3231 |
| 7/18/2018 | 1098.400 | 1010.566 | 0.2882 |
| 7/19/2018 | 1093.300 | 1011.256 | 0.2985 |
| 7/20/2018 | 1113.400 | 1011.951 | 0.2702 |
| 7/23/2018 | 1129.800 | 1012.714 | 0.2493 |
| 7/24/2018 | 1122.000 | 1013.635 | 0.2628 |
| 7/25/2018 | 1110.000 | 1014.384 | 0.2819 |
| 7/26/2018 | 1110.100 | 1015.155 | 0.2818 |
| 7/27/2018 | 1119.500 | 1015.593 | 0.2694 |
| 7/30/2018 | 1130.000 | 1016.105 | 0.2537 |
| 7/31/2018 | 1151.000 | 1016.693 | 0.2282 |
| 8/1/2018 | 1190.400 | 1017.077 | 0.181 |
| 8/2/2018 | 1191.500 | 1018.023 | 0.1809 |
| 8/3/2018 | 1175.000 | 1019.001 | 0.2014 |
| 8/6/2018 | 1176.700 | 1019.350 | 0.2005 |
| 8/7/2018 | 1194.900 | 1020.068 | 0.1807 |
| 8/8/2018 | 1185.000 | 1020.534 | 0.1934 |
| 8/9/2018 | 1221.500 | 1021.220 | 0.1579 |
| 8/10/2018 | 1211.000 | 1021.791 | 0.1695 |
| 8/13/2018 | 1197.550 | 1022.115 | 0.1844 |
| 8/14/2018 | 1190.000 | 1022.856 | 0.194 |
| 8/16/2018 | 1203.250 | 1023.517 | 0.1806 |
| 8/17/2018 | 1209.000 | 1024.495 | 0.1765 |
| 8/20/2018 | 1207.900 | 1025.270 | 0.1798 |
| 8/21/2018 | 1237.250 | 1025.881 | 0.1529 |
| 8/23/2018 | 1246.300 | 1026.357 | 0.1463 |
| 8/24/2018 | 1265.250 | 1027.027 | 0.1295 |
| 8/27/2018 | 1279.400 | 1027.664 | 0.1205 |
| 8/28/2018 | 1296.000 | 1027.860 | 0.108 |
| 8/29/2018 | 1316.300 | 1028.842 | 0.0968 |
| 8/30/2018 | 1293.600 | 1029.407 | 0.1122 |
| 8/31/2018 | 1270.000 | 1030.220 | 0.1318 |
| 9/3/2018 | 1245.000 | 1031.028 | 0.1539 |
| 9/4/2018 | 1235.150 | 1031.522 | 0.1635 |
| 9/5/2018 | 1242.500 | 1032.422 | 0.1597 |
| 9/6/2018 | 1230.150 | 1033.061 | 0.171 |
| 9/7/2018 | 1264.900 | 1033.706 | 0.141 |
| 9/10/2018 | 1275.000 | 1034.310 | 0.1362 |
| 9/11/2018 | 1259.000 | 1035.009 | 0.1504 |
| 9/12/2018 | 1251.800 | 1036.014 | 0.1589 |
| 9/14/2018 | 1259.400 | 1036.480 | 0.1536 |
| 9/17/2018 | 1250.750 | 1037.249 | 0.1612 |
| 9/18/2018 | 1226.000 | 1038.029 | 0.1881 |
| 9/19/2018 | 1224.000 | 1038.905 | 0.1916 |
| 9/21/2018 | 1219.000 | 1039.573 | 0.199 |
| 9/24/2018 | 1214.450 | 1040.290 | 0.2046 |
| 9/25/2018 | 1235.500 | 1040.991 | 0.1835 |
| 9/26/2018 | 1239.000 | 1041.504 | 0.1818 |
| 9/27/2018 | 1255.000 | 1042.349 | 0.169 |
| 9/28/2018 | 1259.900 | 1042.981 | 0.1648 |
| 10/1/2018 | 1257.700 | 1043.566 | 0.1668 |
| 10/3/2018 | 1229.500 | 1044.087 | 0.1952 |
| 10/4/2018 | 1189.500 | 1044.692 | 0.239 |
| 10/5/2018 | 1099.500 | 1045.306 | 0.3642 |
| 10/8/2018 | 1050.000 | 1045.908 | 0.4467 |
| 10/9/2018 | 1121.650 | 1046.592 | 0.3308 |
| 10/10/2018 | 1093.900 | 1047.160 | 0.3764 |
| 10/11/2018 | 1064.000 | 1047.701 | 0.4256 |
| 10/12/2018 | 1104.950 | 1048.345 | 0.3611 |
| 10/15/2018 | 1129.900 | 1049.375 | 0.3266 |
| 10/16/2018 | 1146.000 | 1050.168 | 0.3057 |
| 10/17/2018 | 1179.000 | 1051.058 | 0.2668 |
| 10/19/2018 | 1100.000 | 1051.872 | 0.3741 |
| 10/22/2018 | 1110.000 | 1052.499 | 0.3618 |
| 10/23/2018 | 1052.750 | 1053.511 | 0.4533 |
| 10/24/2018 | 1074.900 | 1054.429 | 0.417 |
| 10/25/2018 | 1036.000 | 1055.063 | 0.4846 |
| 10/26/2018 | 1032.900 | 1055.716 | 0.4909 |
| 10/29/2018 | 1046.000 | 1056.298 | 0.4689 |
| 10/30/2018 | 1085.500 | 1057.027 | 0.4062 |
| 10/31/2018 | 1059.000 | 1057.584 | 0.4526 |
| 11/1/2018 | 1067.900 | 1058.234 | 0.4398 |
| 11/2/2018 | 1067.000 | 1058.955 | 0.4418 |
| 11/5/2018 | 1073.450 | 1059.790 | 0.4343 |
| 11/6/2018 | 1094.000 | 1060.371 | 0.4019 |
| 11/7/2018 | 1115.000 | 1060.924 | 0.3702 |
| 11/9/2018 | 1106.250 | 1061.891 | 0.3846 |
| 11/12/2018 | 1097.700 | 1062.619 | 0.3982 |
| 11/13/2018 | 1074.000 | 1063.101 | 0.4366 |
| 11/14/2018 | 1105.050 | 1063.765 | 0.3907 |
| 11/15/2018 | 1096.950 | 1064.255 | 0.403 |
| 11/16/2018 | 1097.950 | 1065.046 | 0.4023 |
| 11/19/2018 | 1132.900 | 1065.966 | 0.3504 |
| 11/20/2018 | 1145.000 | 1066.691 | 0.3335 |
| 11/21/2018 | 1137.500 | 1067.566 | 0.3455 |
| 11/22/2018 | 1114.500 | 1068.158 | 0.3812 |
| 11/26/2018 | 1109.000 | 1068.420 | 0.3915 |
| 11/27/2018 | 1107.900 | 1069.106 | 0.3923 |
| 11/28/2018 | 1132.450 | 1069.412 | 0.3579 |
| 11/29/2018 | 1161.000 | 1070.142 | 0.3215 |
| 11/30/2018 | 1172.300 | 1070.861 | 0.3089 |
| 12/3/2018 | 1174.900 | 1071.503 | 0.307 |
| 12/4/2018 | 1158.000 | 1072.011 | 0.3282 |
| 12/5/2018 | 1143.750 | 1072.594 | 0.3477 |
| 12/6/2018 | 1149.000 | 1073.536 | 0.3415 |
| 12/7/2018 | 1129.450 | 1074.412 | 0.3704 |
| 12/10/2018 | 1110.000 | 1075.251 | 0.3974 |
| 12/11/2018 | 1066.000 | 1075.994 | 0.467 |
| 12/12/2018 | 1099.000 | 1076.953 | 0.418 |
| 12/13/2018 | 1128.000 | 1077.769 | 0.3786 |
| 12/14/2018 | 1103.100 | 1078.206 | 0.4158 |
| 12/17/2018 | 1115.950 | 1078.956 | 0.3955 |
| 12/18/2018 | 1123.300 | 1079.857 | 0.3868 |
| 12/19/2018 | 1141.500 | 1080.665 | 0.3632 |
| 12/20/2018 | 1121.000 | 1081.233 | 0.3925 |
| 12/21/2018 | 1125.000 | 1082.049 | 0.388 |
| 12/24/2018 | 1100.900 | 1083.013 | 0.4251 |
| 12/26/2018 | 1085.800 | 1083.786 | 0.4497 |
| 12/27/2018 | 1107.200 | 1084.564 | 0.4189 |
| 12/28/2018 | 1125.500 | 1085.323 | 0.3952 |