
A SIMPLE CASE-STUDY DEMONSTRATION ON THE ANALYSIS OF STOCK PRICES USING GEOMETRIC BROWNIAN MOTION

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Abstract

This study centered on the application of the Geometrical Brownian motion in the analysis of stock prices. It featured the estimations of the drift of stock prices, the volatility of stock prices, and the expected values and the associated variances of stock prices at any given time, even in the future. From the illustrative example presented, based on the study data from a Nigeria-based company (with coded name, Omega Ventures), the value of the drift of the weekly stock prices showed that, on the average, the stock prices of the company fell at the rate of 0.000339 weekly for the four year period under study. With the value of volatility obtained revealed that, on the average, the weekly changes in the company's stock prices vary at the rate of 0.020567 – which is considered relatively low – an indication of the estimability of the company's future stock prices. Finally, the future stock prices of the company were estimated, and there was a decrease in stock prices with time within the four year period under study, though it was very minute. Also, there was an increase in the variance of stock prices as the time interval increases.

1. INTRODUCTION

Brownian Motion is a symmetric random walk where each time unit is equally likely to take unit step either to the left or to the right (see, for example, Ross, 1993).

Suppose,

x_t denote the stock price at time, t , in the stock market.

Δx be the unit step either to the left or to the right with equal probability; and

Δt be the unit change in time;

Then,

$$x_t = \Delta x (x_1 + x_2 + \cdots + x_{(t/\Delta t)}) \quad (1.1)$$

where,

$$x_i = \begin{cases} +1; & \text{if the } i^{th} \text{ step is to the right} \\ -1; & \text{if the } i^{th} \text{ step is to the left} \\ 0; & \text{if there is no change when the } i^{th} \text{ step is taken.} \end{cases}$$

1.1 Assumptions of Brownian Motion

Lawlar (1995) gave the followings as the underlying assumptions of the Brownian motion:

- At the initial week, the stock price in the stock market is k . That is, $x_0 = k$.
- The changes in the stock prices in the stock market are independent. Consider the two times, s and t , such that for any $s_1 \leq t_1 \leq s_2 \leq t_2 \leq \dots \leq s_n \leq t_n$, the random variables, $x_{t_1} - x_{s_1}, x_{t_2} - x_{s_2}, \dots, x_{t_n} - x_{s_n}$, are independent.
- The distribution of $x_t - x_s$ depends only on $t - s$.
- For any time, s and t , such that $s < t$, the random variable, $(x_t - x_s) \square N[0, (t - s)\sigma^2]$.
- The function, $x_{(t)}$, is a continuous function of t .

1.2 Types of Brownian Motion

According to Ross (1993), the types of Brownian motion that exist include the followings:

- Geometric Brownian Motion:

Let $x_{(t)}; t \geq 0$ be a Brownian motion; then, the process, $y_{(t)}; t \geq 0$, defined by,

$$y_{(t)} = e^{x_{(t)}} \tag{1.2}$$

is called a Geometric Brownian Motion.

- Brownian Motion Absorbed at a Value:

Let $x_{(t)}$; $t \geq 0$ be a Brownian motion; such that T_x is the first time it hits x ; $x > 0$. Also, let

$$Z_{(t)} = \begin{cases} x_{(t)}; & \text{if } t < T_x \\ x; & \text{if } t \geq T_x \end{cases} \quad (1.3)$$

Thus, $Z_{(t)}$ is a Brownian Motion that when it hits x it remains there forever.

(c) Integrated Brownian Motion:

Let $x_{(t)}$; $t \geq 0$ be a Brownian motion; then the process, $Z_{(t)}$; $t \geq 0$, defined by,

$$Z_{(t)} = \int x_{(s)} ds \quad (1.4)$$

is called an Integrated Brownian Motion.

(d) Brownian Motion Reflected at the Origin:

If $x_{(t)}$; $t \geq 0$ is a Brownian motion; then the process, $Z_{(t)}$; $t \geq 0$, defined by,

$$Z_{(t)} = |x_{(t)}| \quad (1.5)$$

is called a Brownian Motion Reflected at the Origin.

1.3 Areas of Application of the Brownian Motion

The Brownian motion is known to have applications in areas such as stock markets analyses, robotics, decision-making, medical imaging, manufacturing, estimation of floods and droughts, and so on. Most of the applications of the Brownian Motion have been in Stock Market Analyses. In the literatures, so much of the past works have shown authors analyzing trends in, and even predicting stock market behaviours – such as stock market prices and stock market returns using the Geometric Brownian Motion. Some of these past works include, Omar and Jaffar (2011), Brewer, Feng, and Kwan (2012), Abidin and Jaffar (2012; 2014), Gajda and Wylomanska (2012), Reddy and Clinton (2016), Suganthi and Jayalalitha (2019), Rahul and Bidyadhara (2020), Islam and Nguyen (2020), Agbam (2021), and Tassopoulos and Protonotarios (2022).

2. GEOMETRIC BROWNIAN MOTION IN STOCK PRICES ANALYSIS

In simply terms, (1.2) defined the Geometric Brownian Motion. And so,

$$E\left(y_{(t)}\right)=E\left(e^{x_{(t)}}\right)=e^{t/2} \quad (2.1)$$

and

$$\begin{aligned} Var\left(y_{(t)}\right) &= E\left(y_{(t)}^2\right)-\left[E\left(y_{(t)}\right)\right]^2 \\ &= E\left(e^{2x_{(t)}}\right)-e^t=e^{2t}-e^t \end{aligned} \quad (2.2)$$

This is useful in modeling when it is thought that the percentage changes are independent and identically distributed, not the absolute changes.

For instance, suppose that $x_{(t)}$ is the price of stocks at time, t , then it might be reasonable to suppose that $\frac{x_{(t)}}{x_{(t-1)}}$ are independent and identically distributed (see, Ross, 1993).

Clearly, (2.1) and (2.2) show that the Geometric Brownian Motion model only takes into account the time for stock prices instead of the stock prices themselves.

2.1 Estimation of the Drift of Stocks

The drift of the stock market can be estimated from historical data (see, Kolb, 2000). The drift is also known as the Expected Growth Rate (EGR). Let the number of time classification (which could be, say for example, weeks) involved be denoted by n ; P_t be the price at week t ; and the Price Relative for week t be PR_t ; such that,

$$PR_t = \frac{P_t}{P_{t-1}} \quad (2.3)$$

and

$$Drift, \mu = \frac{1}{n} \sum_{t=1}^n \ln\left(PR_t\right) \quad (2.4)$$

2.2 Estimation of the Volatility of Stocks

The volatility of stocks can also be estimated from historical data. Let n , P_t , PR_t be as defined in Section 2.1, and $\ln(PR_t)$ be the logarithmic relative prices such that, $[\ln(PR_t) - PR_\mu]^2$ be the square of the deviations from the drift (see, for example, Kolb, 2000). Thus, the volatility is given by,

$$\text{Volatility, } \sigma^2 = \frac{1}{n-1} \sum_{t=1}^n [\ln(PR_t) - PR_\mu]^2 \quad (2.5)$$

where,

$$PR_\mu = \frac{1}{n} \quad (2.6)$$

It should be noted that (2.5) takes into account the current and instantaneous standard deviation from the stock. That is to say, that the immediate volatility of the stock is the riskiness of the stock that affects the option price. Consequently, the higher the volatility, the more impossible it becomes to estimate stock prices.

2.3 Estimation of Expected Stock Prices

Let,

x_t be the stock price at the beginning of the time interval;

Δx be the change in stock price at that time, Δt ; such that,

$$\Delta x = x_{t-1} - x_t \quad (2.7)$$

and let $x_{(t)}\mu\Delta t$ be the expected value of the stock price change during time Δt .

Thus, the expected stock price at any given time is given by,

$$E(x_{(t+\Delta t)}) = x_t e^{\mu\Delta t} \quad (2.8)$$

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This is to say that the expected stock price at time, $t + \Delta t$, depends on the original stock price, x_t , the drift, μ , and the elapsed time, Δt .

2.4 Estimation of Variance of Stock Prices

Let μ , δ^2 , Δt , and $t + \Delta t$ be as earlier defined; then, the variance of stock prices at time, $t + \Delta t$, is given by,

$$Var(x_{(t+\Delta t)}) = x_t^2 e^{2\mu\Delta t} (e^{\delta^2\Delta t} - 1) \quad (2.9)$$

which can be traced using the variance formular, from first principles, given by,

$$Var(x) = E(x^2) - [E(x)]^2 \quad (2.10)$$

Thus, from (2.9), the variance of stock prices depends on the original stock price, the expected growth rate (that is, the drift), and the elapsed time. The implication here is that the longer the time interval, the longer the variance; and an increase in the variance would reflect a greater uncertainty about stock prices in the future.

3. A CASE-STUDY DEMONSTRATION

The concept of the Geometric Brownian Motion as a technique of analyzing stock prices shall be demonstrated by using the procedure described in Section 2 on the study data in Table 1. The study data represent the average weekly stock prices (in Nigerian Naira (₦)) of an anonymous company (say, for label purposes, is identified herein as Omega Ventures) for a period of four years. The data in the table comprise of a total of 192 weekly stock prices of Omega Ventures.

Table 1: the Average Weekly Value of Stock Prices of Omega Ventures for 4 Years

Yr.	Wk.	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 st	1	23.50	25.50	28.48	28.08	30.47	33.97	33.47	22.66	22.77	23.36	23.55	24.36
	2	27.28	26.73	28.04	28.59	32.69	32.12	28.01	21.70	20.78	24.67	28.83	24.14
	3	20.53	26.52	27.83	28.44	32.96	32.18	24.50	22.33	22.64	24.71	24.40	24.12
	4	26.82	27.46	26.16	29.22	33.92	32.80	25.88	22.26	24.98	23.50	24.83	23.78
2 nd	1	23.89	22.29	24.52	22.20	25.44	24.62	24.45	22.27	20.51	19.54	19.62	18.70
	2	24.12	21.29	24.31	22.46	26.05	25.47	27.96	21.82	20.37	19.98	19.57	19.16

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	3	23.91	22.06	23.99	23.93	26.17	25.84	24.82	21.06	20.07	19.77	10.43	19.55
	4	23.91	23.20	23.47	24.08	20.44	25.88	21.04	20.92	20.04	19.83	19.09	21.21
3 rd	1	20.71	24.29	26.63	25.65	26.12	28.07	22.87	20.08	20.00	20.00	20.00	20.00
	2	22.48	27.29	26.79	26.16	25.96	27.87	27.99	20.00	20.00	20.00	20.00	20.00
	3	24.90	27.32	25.56	26.06	28.36	27.99	29.37	20.00	20.00	20.00	20.00	20.00
	4	23.77	26.33	26.61	24.05	28.63	29.37	29.37	20.00	20.00	20.00	20.00	20.00
4 th	1	20.00	20.00	20.00	29.17	29.27	28.63	29.37	29.04	22.45	22.64	24.99	23.26
	2	20.00	20.00	20.00	29.29	30.01	29.73	28.72	24.38	23.56	23.27	25.02	21.12
	3	20.00	20.00	20.00	29.23	30.19	29.33	31.11	21.86	23.16	23.03	25.25	21.02
	4	20.00	20.00	20.00	20.72	30.26	30.06	24.66	23.62	23.62	22.71	24.82	22.02

3.1 Tests of Basic Assumptions

The dataset were tested for some basic assumptions, which included the normality test, test for time-dependency, as well as test for the presence of outlier(s). The dataset actually satisfied the three assumptions.

3.2 Estimation of the Drift of the Weekly Stocks of Omega Ventures

The drift of the weekly stocks of Omega Ventures in Table 1 is obtained by firstly determining PR_t using (2.3) and then $\ln(PR_t)$ (see Table 2 in Appendix I). Now, using (2.4), the Drift of stocks becomes,

$$\text{Drift, } \mu = \frac{1}{192}(-0.06509) = -0.000339$$

This result implies that, on the average, the stock prices of Omega Ventures decreased weekly at the rate of 0.000339 for the four (4) year period under study.

3.3 Estimation of the Volatility of Weekly Stocks of Omega Ventures

Based on (2.5) and (2.6), the quantity, $\{\ln(PR_t) - PR_\mu\}^2$ was determined for each of the week for the 4 years period; and the outcomes are presented also in Table 2. Using (2.5), the volatility of Omega Ventures stocks is,

$$\text{Volatility, } \delta^2 = \frac{1}{192-1}(3.928386) = 0.020567$$

where,

$$PR_{\mu} = \frac{1}{192} = 0.0052$$

This result for the volatility of weekly stocks of Omega Ventures ($=0.020567$) is actually low. Thus, it is possible to estimate the weekly stock prices of Omega Ventures.

3.4 Estimation of Weekly Stock Prices of Omega Ventures

Having estimated the stock's drift and also shown the estimability of Omega Ventures given its low volatility, the stock price of Omega Ventures expected at any given week can be estimated. Employing (2.8), the expected stock prices of Omega Ventures are estimated.

For instance, given the stock price at the initial week, $t=0$, to be $x_0 = \text{N}22.02$, the estimated stock price for the next week will be;

$$E\left(x_{(0+1)}\right) = 22.02e^{(-0.000339)(1)} = \text{N}22.01$$

the estimated stock price for the next two weeks will be;

$$E\left(x_{(0+2)}\right) = 22.02e^{(-0.000339)(2)} = \text{N}22.01$$

the estimated stock price for the next five weeks will be;

$$E\left(x_{(0+5)}\right) = 22.02e^{(-0.000339)(5)} = \text{N}21.98$$

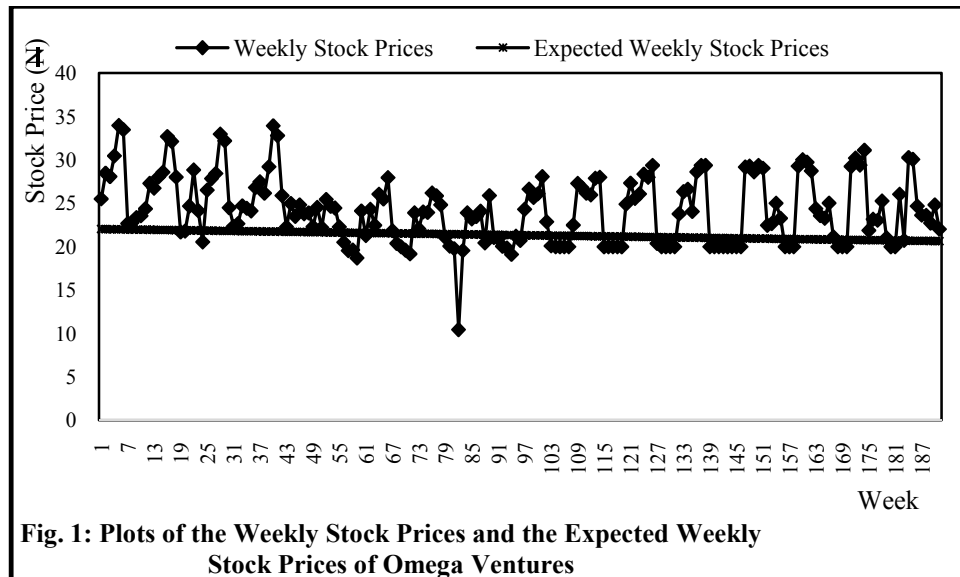
the estimated stock price for the next fifteen weeks will be;

$$E\left(x_{(0+15)}\right) = 22.02e^{(-0.000339)(15)} = \text{N}21.91$$

the estimated stock price for the next thirty weeks will be;

$$E\left(x_{(0+30)}\right) = 22.02e^{(-0.000339)(30)} = \text{N}21.80$$

The estimates of the expected weekly stock prices of Omega Ventures are also presented in Table 2. Also, line plots of both the original and the estimated (expected) weekly stock prices of Omega Ventures are presented in Figure 1.



Although the weekly stock prices of Omega Ventures exhibited upward and downward movement across the period under study, it is evident – from the results obtained – that the expected weekly stock prices of Omega Ventures decreased with time, but at a very small rate.

3.5 Estimation of Variance of Weekly Stock Prices of Omega Ventures

Employing (2.9); and given that the price at the initial week, $t = 0$, to be $x_0 = ₦22.02$, the estimated variance of stock price for the next one week will be;

$$Var(x_{(0+1)}) = (22.02)^2 e^{(2)(-0.000339)(1)} \left[e^{(0.020567)(1)} - 1 \right] = ₦10.06$$

the estimated variance of stock price for the next two weeks will be;

$$Var(x_{(0+2)}) = (22.02)^2 e^{(2)(-0.000339)(2)} \left[e^{(0.020567)(2)} - 1 \right] = ₦20.33$$

the estimated variance of stock price for the next five weeks will be;

$$Var(x_{(0+5)}) = (22.02)^2 e^{(2)(-0.000339)(5)} \left[e^{(0.020567)(5)} - 1 \right] = ₦52.45$$

the estimated variance of stock price for the next fifteen weeks will be;

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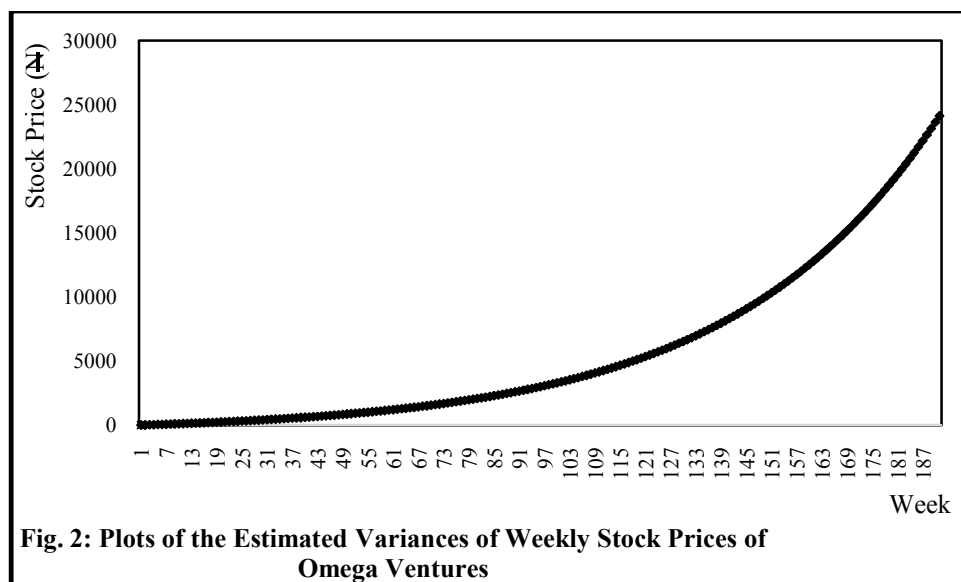
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$$Var(x_{(0+15)}) = (22.02)^2 e^{(2)(-0.000339)(15)} \left[e^{(0.020567)(15)} - 1 \right] = \text{N}174.99$$

and the estimated variance of stock price for the next thirty weeks will be;

$$Var(x_{(0+30)}) = (22.02)^2 e^{(2)(-0.000339)(30)} \left[e^{(0.020567)(30)} - 1 \right] = \text{N}413.23$$

The entire estimated variances of weekly stock prices of Omega Ventures are also presented in Table 2, and are equally represented graphically in Figure 2. Also, line plots of the estimated variances of the weekly stock prices of Omega Ventures are presented in Figure 2.



The results of the estimated variances of the weekly stock prices of Omega Ventures indicate that the higher the time interval, the higher the variance of the weekly stock prices of Omega Ventures.

4. CONCLUSION

This study illustrated the use of the Geometrical Brownian motion in analyzing stock prices. It featured the estimations of the drift of stock prices, the volatility of stock prices, and

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the expected values and the associated variances of stock prices at any given time, even in the future.

From the illustrative example presented, which was based on the study data of Omega Ventures, the value of the drift of the weekly stock prices showed that, on the average, the stock prices of the company fell at the rate of 0.000339 weekly for the four year period under study. The value of volatility obtained revealed that, on the average, the weekly changes in the company's stock prices vary at the rate of 0.020567 – which is considered relatively low – an indication of the estimability of the company's future stock prices. Finally, the future stock prices of the company were estimated, and there was a decrease in weekly stock prices with time within the four year period under study, though it was very minute. Also, there was an increase in the variance of stock prices as the time interval increases.

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APPENDIX

Table 2: Computation of Drift, Volatility, Expected, and Variance of Weekly Stock Prices for Omega Ventures

Week (t)	P_t	PR_t	$\ln(PR_t)$	$\ln(PR_t) - PR_\mu$	$E(x_{(t+\Delta t)})$	$Var(x_{(t+\Delta t)})$
0	23.50	-	-	-	-	-
1	25.50	1.08511	0.08168	0.00585	22.0125	10.06214
2	28.48	1.11686	0.11052	0.01109	22.0051	20.33337
3	28.08	0.98596	-0.01414	0.00037	21.9976	30.81804
4	30.47	1.08511	0.08168	0.00585	21.9902	41.52058
5	33.97	1.11487	0.10874	0.01072	21.9827	52.44552
6	33.47	0.98528	-0.01483	0.00040	21.9753	63.59747

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7	22.66	0.67702	-0.39005	0.15623	21.9678	74.98117
8	22.77	1.00485	0.00484	0.00000	21.9604	86.60141
9	23.36	1.02591	0.02558	0.00041	21.9529	98.46313
10	23.55	1.00813	0.00810	0.00000	21.9455	110.5713
11	24.36	1.03439	0.03381	0.00082	21.938	122.9311
12	27.28	1.11987	0.11321	0.01166	21.9306	135.5478
13	26.73	0.97984	-0.02037	0.00065	21.9232	148.4266
14	28.04	1.04901	0.04785	0.00182	21.9157	161.573
15	28.59	1.01961	0.01942	0.00020	21.9083	174.9927
16	32.69	1.14341	0.13402	0.01659	21.9009	188.6911
17	32.12	0.98256	-0.01759	0.00052	21.8935	202.6743
18	28.01	0.87204	-0.13692	0.02020	21.886	216.948
19	21.70	0.77472	-0.25525	0.06784	21.8786	231.5183
20	21.78	1.00369	0.00368	0.00000	21.8712	246.3914
21	24.67	1.13269	0.12460	0.01425	21.8638	261.5735
22	28.83	1.16863	0.15583	0.02269	21.8564	277.0711
23	24.14	0.83732	-0.17755	0.03340	21.849	292.8908
24	20.53	0.85046	-0.16198	0.02795	21.8416	309.0392
25	26.52	1.29177	0.25601	0.06290	21.8342	325.5232
26	27.83	1.04940	0.04822	0.00185	21.8268	342.3497
27	28.44	1.02192	0.02168	0.00027	21.8194	359.5258
28	32.96	1.15893	0.14750	0.02025	21.812	377.0589
29	32.18	0.97633	-0.02395	0.00085	21.8046	394.9563
30	24.50	0.76134	-0.27268	0.07722	21.7972	413.2256
31	22.33	0.91143	-0.09274	0.00959	21.7898	431.8746
32	22.64	1.01388	0.01378	0.00007	21.7824	450.9111
33	24.71	1.09143	0.08749	0.00677	21.775	470.3431
34	24.40	0.98745	-0.01263	0.00032	21.7677	490.179
35	24.12	0.98852	-0.01155	0.00028	21.7603	510.427
36	26.82	1.11194	0.10611	0.01018	21.7529	531.0958
37	27.46	1.02386	0.02358	0.00034	21.7455	552.1941
38	26.16	0.95266	-0.04850	0.00288	21.7382	573.7308
39	29.22	1.11697	0.11062	0.01111	21.7308	595.715
40	33.92	1.16085	0.14915	0.02072	21.7234	618.1561
41	32.80	0.96698	-0.03358	0.00150	21.7161	641.0635
42	25.88	0.78902	-0.23696	0.05865	21.7087	664.4469
43	22.26	0.86012	-0.15068	0.02430	21.7013	688.3162

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44	24.98	1.12219	0.11528	0.01212	21.694	712.6816
45	23.50	0.94075	-0.06108	0.00439	21.6866	737.5532
46	24.83	1.05660	0.05506	0.00249	21.6793	762.9417
47	23.78	0.95771	-0.04321	0.00234	21.6719	788.8577
48	23.89	1.00463	0.00462	0.00000	21.6646	815.3123
49	22.29	0.93303	-0.06932	0.00555	21.6572	842.3166
50	24.52	1.10004	0.09535	0.00813	21.6499	869.882
51	22.20	0.90538	-0.09940	0.01094	21.6426	898.0203
52	25.44	1.14595	0.13623	0.01717	21.6352	926.7432
53	24.62	0.96777	-0.03276	0.00144	21.6279	956.0631
54	24.45	0.99310	-0.00692	0.00015	21.6206	985.9921
55	22.27	0.91084	-0.09339	0.00972	21.6132	1016.543
56	20.51	0.92097	-0.08233	0.00766	21.6059	1047.729
57	19.54	0.95271	-0.04844	0.00288	21.5986	1079.563
58	19.62	1.00409	0.00408	0.00000	21.5913	1112.058
59	18.70	0.95311	-0.04802	0.00283	21.584	1145.229
60	24.12	1.28984	0.25452	0.06216	21.5766	1179.089
61	21.29	0.88267	-0.12480	0.01690	21.5693	1213.653
62	24.31	1.14185	0.13265	0.01624	21.562	1248.934
63	22.46	0.92390	-0.07915	0.00712	21.5547	1284.949
64	26.05	1.15984	0.14828	0.02047	21.5474	1321.713
65	25.47	0.97774	-0.02251	0.00077	21.5401	1359.24
66	27.96	1.09776	0.09327	0.00775	21.5328	1397.547
67	21.82	0.78040	-0.24795	0.06409	21.5255	1436.65
68	20.37	0.93355	-0.06876	0.00547	21.5182	1476.566
69	19.98	0.98085	-0.01934	0.00060	21.5109	1517.311
70	19.57	0.97948	-0.02073	0.00067	21.5036	1558.903
71	19.16	0.97905	-0.02117	0.00070	21.4963	1601.359
72	23.91	1.24791	0.22147	0.04677	21.489	1644.697
73	22.06	0.92263	-0.08053	0.00735	21.4818	1688.936
74	23.99	1.08749	0.08387	0.00619	21.4745	1734.094
75	23.93	0.99750	-0.00250	0.00006	21.4672	1780.191
76	26.17	1.09361	0.08948	0.00677	21.4599	1827.245
77	25.84	1.98739	-0.01269	0.00032	21.4526	1875.277
78	24.82	0.96053	-0.04027	0.00207	21.4454	1924.308
79	21.06	0.84851	-0.16427	0.02872	21.4381	1974.357
80	20.07	0.95299	-0.04815	0.00285	21.4308	2025.446

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81	19.77	0.98505	-0.01506	0.00041	21.4236	2077.597
82	10.43	0.52757	-0.63947	0.41561	21.4163	2130.831
83	19.55	1.87440	0.62829	0.38823	21.4091	2185.172
84	23.91	1.22302	0.20132	0.03846	21.4018	2240.642
85	23.20	0.97031	-0.03014	0.00125	21.3945	2297.265
86	23.47	1.01164	0.01157	0.00004	21.3873	2355.064
87	24.08	1.02599	0.02566	0.02859	21.38	2414.064
88	20.44	0.84884	-0.16388	0.02859	21.3728	2474.29
89	25.88	1.26614	0.23597	0.05325	21.3656	2535.768
90	21.04	0.81298	-0.20705	0.04505	21.3583	2598.523
91	20.92	0.99430	-0.00572	0.00012	21.3511	2662.583
92	20.04	0.95793	-0.04298	0.00232	21.3438	2727.973
93	19.83	0.98952	-0.01054	0.00025	21.3366	2794.723
94	19.09	0.96268	-0.03803	0.00187	21.3294	2862.859
95	21.21	1.11105	0.10531	0.01002	21.3221	2932.411
96	20.71	0.97643	-0.02385	0.00084	21.3149	3003.409
97	24.29	1.17286	0.15945	0.02379	21.3077	3075.881
98	26.63	1.09634	0.09198	0.00753	21.3005	3149.86
99	25.65	0.96320	-0.03749	0.00182	21.2933	3225.376
100	26.12	1.01832	0.01815	0.00017	21.286	3302.462
101	28.07	1.07466	0.07200	0.00446	21.2788	3381.149
102	22.87	0.81475	-0.20487	0.04413	21.2716	3461.471
103	20.08	0.87801	-0.13010	0.01831	21.2644	3543.463
104	20.00	0.99602	-0.00399	0.00008	21.2572	3627.158
105	20.00	1.00000	0.00000	0.00003	21.25	3712.592
106	20.00	1.00000	0.00000	0.00003	21.2428	3799.802
107	20.00	1.00000	0.00000	0.00003	21.2356	3888.823
108	22.48	1.12400	0.11689	0.01247	21.2284	3979.695
109	27.29	1.21397	0.19390	0.03560	21.2212	4072.455
110	26.79	0.98168	-0.01849	0.00056	21.214	4167.143
111	26.16	0.97648	-0.02380	0.00084	21.2068	4263.798
112	25.96	0.99235	-0.00768	0.00017	21.1996	4362.462
113	27.87	1.07357	0.07099	0.00433	21.1924	4463.176
114	27.99	1.00431	0.00430	0.00000	21.1852	4565.982
115	20.00	0.71454	-0.33612	0.11651	21.1781	4670.925
116	20.00	1.00000	0.00000	0.00003	21.1709	4778.049
117	20.00	1.00000	0.00000	0.00003	21.1637	4887.399

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118	20.00	1.00000	0.00000	0.00003	21.1565	4999.021
119	20.00	1.00000	0.00000	0.00003	21.1494	5112.963
120	24.90	1.24500	0.21914	0.04577	21.1422	5229.272
121	27.32	1.09719	0.09275	0.00766	21.135	5347.998
122	25.56	0.93558	-0.06659	0.00515	21.1279	5469.192
123	26.06	1.01956	0.01937	0.00020	21.1207	5592.903
124	28.36	1.08826	0.08458	0.00630	21.1136	5719.186
125	27.99	0.98695	-0.01314	0.00034	21.1064	5848.092
126	29.37	1.04930	0.04812	0.00184	21.0992	5979.678
127	20.37	0.68097	-0.38424	0.15167	21.0921	6113.997
128	20.00	1.00000	0.00000	0.00003	21.0849	6251.108
129	20.00	1.00000	0.00000	0.00003	21.0778	6391.068
130	20.00	1.00000	0.00000	0.00003	21.0707	6533.936
131	20.00	1.00000	0.00000	0.00003	21.0635	6679.773
132	23.77	1.18850	0.17269	0.02805	21.0564	6828.641
133	26.33	1.10770	0.10229	0.00942	21.0492	6980.602
134	26.61	1.01063	0.01057	0.00003	21.0421	7135.72
135	24.05	0.90380	-0.10115	0.01131	21.035	7294.062
136	28.63	1.19044	0.17432	0.02860	21.0278	7455.695
137	29.37	1.02585	0.02552	0.00041	21.0207	7620.686
138	29.37	1.00000	0.00000	0.00003	21.0136	7789.106
139	20.00	0.68097	-0.38424	0.15167	21.0065	7961.025
140	20.00	1.00000	0.00000	0.00003	20.9993	8136.517
141	20.00	1.00000	0.00000	0.00003	20.9922	8315.656
142	20.00	1.00000	0.00000	0.00003	20.9851	8498.517
143	20.00	1.00000	0.00000	0.00003	20.978	8685.178
144	20.00	1.00000	0.00000	0.00003	20.9709	8875.718
145	20.00	1.00000	0.00000	0.00003	20.9638	9070.217
146	20.00	1.00000	0.00000	0.00003	20.9567	9268.758
147	29.17	1.45850	0.37741	0.13853	20.9496	9471.424
148	29.27	1.00343	0.00342	0.00000	20.9425	9678.302
149	28.63	0.97813	-0.02211	0.00075	20.9354	9889.479
150	29.37	1.02585	0.02552	0.00041	20.9283	10105.04
151	29.04	0.98876	-0.01130	0.00027	20.9212	10325.09
152	22.45	0.77307	-0.25739	0.06896	20.9141	10549.71
153	22.64	1.00846	0.00842	0.00001	20.907	10778.99
154	24.99	1.10380	0.09876	0.00875	20.8999	11013.04

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155	23.26	0.93077	-0.07174	0.00592	20.8928	11251.95
156	20.00	0.85985	-0.15100	0.02440	20.8858	11495.83
157	20.00	1.00000	0.00000	0.00003	20.8787	11744.77
158	20.00	1.00000	0.00000	0.00003	20.8716	11998.89
159	29.29	1.46450	0.38151	0.14160	20.8645	12258.29
160	30.01	1.02458	0.02428	0.00036	20.8574	12523.08
161	29.73	0.99067	-0.00937	0.00021	20.8504	12793.37
162	28.72	0.96603	-0.03458	0.00158	20.8433	13069.28
163	24.38	0.84889	-0.16383	0.02857	20.8362	13350.92
164	23.56	0.96637	-0.03421	0.00155	20.8292	13638.41
165	23.27	0.98769	-0.01239	0.00031	20.8221	13931.88
166	25.02	1.07520	0.07251	0.00453	20.8151	14231.45
167	21.12	0.84412	-0.16946	0.03051	20.808	14537.24
168	20.00	0.94697	-0.05449	0.00356	20.801	14849.38
169	20.00	1.00000	0.00000	0.00003	20.7939	15168.02
170	20.00	1.00000	0.00000	0.00003	20.7869	15493.27
171	29.23	1.46150	0.37946	0.14006	20.7798	15825.28
172	30.19	1.03284	0.03231	0.00073	20.7728	16164.19
173	29.39	0.97350	-0.02686	0.00103	20.7657	16510.14
174	31.11	1.05852	0.05687	0.00267	20.7587	16863.29
175	21.86	0.70267	-0.35287	0.12822	20.7517	17223.77
176	23.16	1.05947	0.05777	0.00276	20.7446	17591.74
177	23.03	0.99439	-0.00563	0.00012	20.7376	17967.36
178	25.25	1.09640	0.09203	0.00754	20.7306	18350.78
179	21.02	0.83248	-0.18335	0.03555	20.7235	18742.17
180	20.00	0.95147	-0.04975	0.00302	20.7165	19141.69
181	20.00	1.00000	0.00000	0.00003	20.7095	19549.52
182	26.04	1.30200	0.26390	0.06692	20.7025	19965.82
183	20.72	0.79570	-0.22853	0.05463	20.6955	20390.77
184	30.26	1.46042	-.37872	0.13951	20.6884	20824.55
185	30.06	0.99339	-0.00663	0.00014	20.6814	21267.35
186	24.66	0.82036	-0.19801	0.04130	20.6744	21719.34
187	23.62	0.95783	-0.04308	0.00233	20.6674	22180.73
188	23.62	1.00000	0.00000	0.00003	20.6604	22651.71
189	22.71	0.96147	-0.03929	0.00198	20.6534	23132.47
190	24.82	1.09291	0.08884	0.00699	20.6464	23623.23
191	22.02	0.88719	-0.11970	0.01560	20.6394	24124.18

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TOTAL	4656.18	192.91026	-0.06509	3.928386		
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