ANOMALOUS BEHAVIOR OF THE VOLATILITY OF DJIA OVER THE LAST CENTURY

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Abstract

This study explores month effects in terms of standard deviations of monthly and daily percentage changes of the Dow Jones Industrial Average. During the last century, the standard deviation of the monthly percentage changes of April (6.63%) is significantly higher than the standard deviations for the other months. The monthly standard deviations of daily percentage changes as a measure of volatility exhibit a slightly rising trend, peaking in October and are all significantly different from zero. The mean monthly standard deviation of daily percentage changes for October (1.08%) was the maximum and also significantly higher than the means of the other months. The DJIA became less volatile in terms of monthly as well as daily percentage changes during the second half of the last century compared to the first half. If we divide the data for the last century into decades, the thirties stand out as the most volatile period in terms of monthly as well as daily percentage changes. Based on both dimensions, the decades prior to 1940 experienced higher standard deviations compared to the subsequent decades. So it appeared that the stock market became more volatile in recent times – but that was in points, not in percentage terms.

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I. INTRODUCTION

Existence of market anomalies have been explored for various assets based on their returns. Al least two studies have looked at the day-of the-week effect in the volatility of stock markets (Berument and Klymaz [2001] and Kiymaz and Berument [2003]). Possibly no study has looked at the existence of month effect in terms of volatilities. If the markets are highly efficient, we would not expect to see significant month-to-month differences in volatilities. We intend to contribute to the formidable literature on market anomalies by exploring month-to-month differences in volatilities in the Dow Jones Industrial Average – the most popular stock index in the world. We also want to explore if volatilities have increased in recent decades as is the popular perception.

We explore volatility of the DJIA from January 1900 to December 1999 principally from two perspectives: (a) if the standard deviation of the monthly percentage changes for a month was different from the standard deviations of all the other months, and (b) if the monthly standard deviations based on daily percentage changes for a month was different from the standard deviations of all the other months. The findings of the study will guide practicing analysts to achieve better timing for investing in large stocks.

The next section describes the methodology used, description of data and descriptive statistics, analysis of results, and finally we summarize and conclude.

II. RESEARCH METHODOLOGY

For the first study, our data consists of the percentage changes in the monthly closing values of the Dow Jones Industrial Average (DJIA) from January 1900 until December 1999. The DJIA is stock-price weighted and hence does not include dividends. It may seem that analysis of month effect will be affected by the omission of dividends. Lakonishok and Smidt (1988) find that this omission does not seem to affect their results with respect to month effect. Hence we do not include dividends.

For the second study we find the monthly standard deviation based on daily percentage changes from January 1900 until December 1999.

If there are n trading days in a certain month, we compute the monthly standard deviation of daily percentage changes, d_i, in DJIA for month t, denoted s_t, as follows:

$$s_t = \sqrt{\frac{\sum_{i=1}^{n}(d_i - \bar{d})^2}{n-1}} \qquad (1)$$

In addition to analyzing the data for the single period (January 1900 to December 1999), we divided the entire period into the following sub-periods to gain deeper insight about the volatility of the DJIA:

Two fifty-year periods:

January 1900 to December 1949

January 1950 to December 1999

Four twenty-five year periods:

January 1900 to December 1924

January 1925 to December 1949

January 1950 to December 1974

January 1975 to December 1999

Ten 10-year periods:

January 1900 to December 1909

January 1910 to December 1919

Thus, in addition to the entire period, we have 16 sub-periods.[1] We hope to show that contrary to popular belief, the DJIA did not increase in volatility in recent decades either based on volatility computed based on monthly changes or daily changes.

We first look at the statistical descriptives for the period January 1900 to December 1999. We present distribution of the monthly percentage changes as well as monthly standard deviations and test each distribution for normality through the Jarque-Bera statistic. This widely used statistics is based on the values of skewness and kurtosis of sample data. For large n, with skewness S and kurtosis K under the normality

[1] For brevity, we do not report results for the decade wise study.

condition, the Jarque-Bera statistic $= \frac{n}{6}\left(S^2 + \frac{(K-3)^2}{4}\right)$ follows a Chi-square distribution with 2 degrees of freedom.

Many studies have used the dummy variable methodology to detect market seasonality. Chien, Lee and Wang (2002) provide statistical analysis and empirical evidence that the methodology may provide misleading results. We avoid this methodology.

We test the following hypotheses:

1. If the variability of the percentage changes for a given month is significantly different from the remaining eleven months. The hypothesis test for a given month *i* is: H_o: $\sigma_i^2 = \sigma_j^2$ vs. H_o: $\sigma_i^2 \neq \sigma_j^2$, where j = {1, 2, …, i-1, i+1, ,,,, , 11, 12}.
2. If the means of the monthly standard deviations of daily percentage changes of a given month is different from the means of the monthly standard deviations of the other eleven months. The hypothesis test for a given month *i* is: H_o: $\mu_i = \mu_j$ vs. H_o: $\mu_i \neq \mu_j$, where j = {1, 2, …, i-1, i+1, …, 11, 12}.

Since we found the variances for the periods i and j to be unequal in many cases, for both cases we decided to use the more conservative t-test assuming unequal variances.

III. THE DATA AND DESCRIPTIVE STATISTICS

The data consists of 1,196 values of monthly percentage changes and monthly standard deviations of DJIA from the January 1900 to December 1999. The stock market was closed because of the First World War from August through November of 1914.

Over this period, the value of DJIA increased from 66.08 at the end of December 1899 to 10,786.85 at the end of December 1999 – a 16,052.82% increase – with an average percentage change of 0.58% per month or 7.00% per year (this excludes dividends). The mean monthly percentage change in the DJIA for the total period is highly significant (p = 0.00). The standard deviation of the monthly percentage changes was 5.48% or 18.97% annualized, which is close to the 20.50% standard deviation of the

annual returns of the S&P 500 Index for the period 1926 to 2004. The summary statistics of the monthly percentage changes for the 1900-1999 period are given in Table 1.

Table 1: Monthly Percentage Changes in DJIA: 1900-1999

Monthly Percentage Change in DJIA	
Observations	1,196
Mean	0.58
Median	0.84
Standard Deviation	5.48
Skewness	-0.05
Kurtosis	6.42
Minimum	-30.70
Maximum	40.18

As we can see in the histogram below of the monthly percentage changes in the DJIA for the entire period, the distribution is slightly skewed to the left as the mean of 0.58% is smaller than the median of 0.84% per month. The skewness equals –0.05 and the kurtosis equals 6.42. The Jarque-Bera statistic equals 581.50 for p-value of less than 0.01. Since the p-value is less than 0.05, the normality assumption is violated. When sample size is large, as is in our case, even unimportant deviations from normality become technically significant. For this reason, we need to use other bases of judgment such as histogram. If we examine, the histogram in Figure I, the distribution appears quite normal in shape. Assuming normal distribution, the probability that DJIA would increase in a certain month is 54% vs. 46% probability that the DJIA would decrease in the same month.

Figure I: Histogram of monthly percentage changes of DJIA: 1900-1999

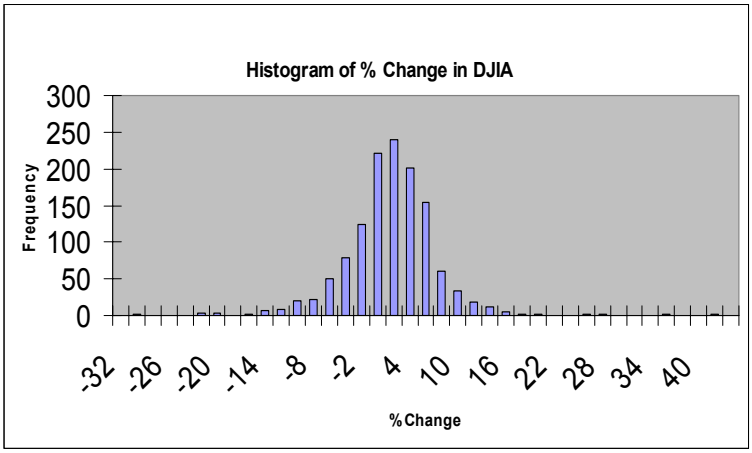


Table 2 shows the frequency of monthly increases every decade that were more than 10% and Table 3 shows the frequency of monthly decreases that were larger than -10%. There were a total of 74 such instances from 1900 to 1999. Of those, 27 occurred during 1900-1929, 32 occurred during 1930-1939, just two occurred during 1940-1969 period and the remaining 13 occurred during 1970-1999 period. Over the entire 1900-1999 period, August and November experienced 6 increases larger than 10% followed by April with 5 and June and August with 4 such increases. Over the entire period, October has suffered 7 decreases larger than 10% followed by November with 6 and September with 5 such decreases.

Table 2

Number of Monthly Increases Larger than 10%

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1900-09			1				1				2	1	5
1910-19			1	1	1				2				5
1920-29			1			1		1			1		4
1930-39		1		2	1	3	1	2	1		2		13
1940-49													0
1950-59													0
1960-69											1		1
1970-79	2			1									3
1980-89	1							1		1			3
1990-99				1									1
Total	3	1	3	5	2	4	2	4	3	1	6	1	35

Table 3

Number of Monthly Decreases Larger than 10%

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1900-09			1				1		1	1			4
1910-19							1			1	1	2	5
1920-29		1								1	2		4
1930-39		1	3	2	2	1			3	3	2	2	19
1940-49					1								1
1950-59													0
1960-69													0
1970-79								1	1		1		3
1980-89										1			1
1990-99								2					2
Total	0	2	4	2	3	1	2	3	5	7	6	4	39

Looking at individual values of the monthly percentage changes, the DJIA increased by as much as 40.18% during April 1933 and declined by as much as 30.70% in September 1931. In the post-Second World War period, the biggest increase was 14.41% in January 1976 and the biggest decline was 23.22% in October 1987 (the month that included "Black Monday").

Turning our attention to volatility, the data consists of 1,196 values of monthly standard deviations of daily percentage changes in DJIA from January 1900 to December 1999.[2] Over this period, the value of monthly standard deviation of daily percentage changes has varied from as low as 0.23% in April of 1965 to as large as 6.21% in October 1987 (the month that included "Black Monday") and 6.36% in December 1914. The average monthly standard deviation of daily percentage changes for the entire period from 1900-1999 equals 0.90%, which is highly significant ($p = 0.00$). The summary statistics of the monthly standard deviation of daily percentage changes for 1900-1999 period are given in Table 4.

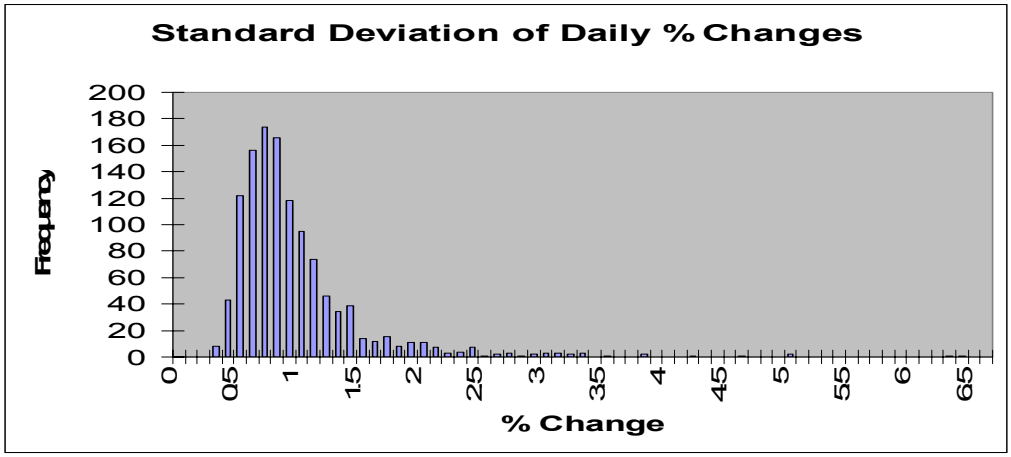
[2] August through November of 1914 are not included in the data set as the stock market was closed because of the First World War.

Table 4: Monthly Standard Deviation of Daily Percentage Changes: 1900-1999

Monthly standard Deviation of Daily Percentage Changes	
Observations	1,196
Mean	0.90
Median	0.75
Standard Deviation	0.57
Skewness	3.66
Kurtosis	21.63
Minimum	0.23
Maximum	6.36

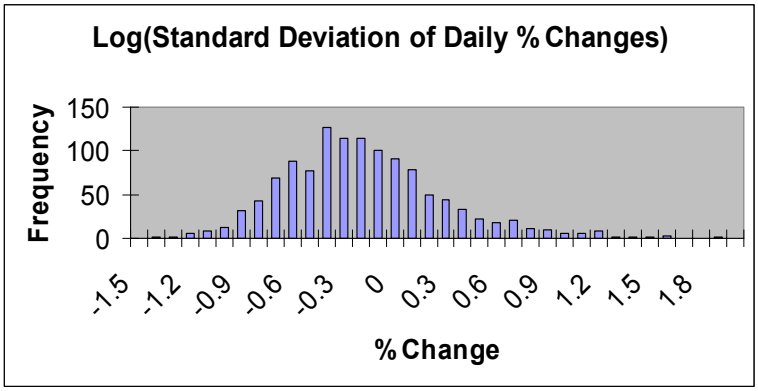
As we can see in the histogram below (Figure II) of the monthly standard deviation of daily percentage changes in the DJIA for the entire period, the distribution is skewed to the right as the mean of 0.90% is larger than the median of 0.75%. The skewness equals 3.66 and the kurtosis equals 21.63. Jarque-Bera statistic equals 19,963 for a p-value of less than 0.01. Since the p-value is less than 0.05, the normality assumption is violated. When sample size is large, as is in our case, even unimportant deviations from normality become technically significant. For this reason, we need to use other bases of judgment such as histogram. If we examine the histogram given below, the distribution does appear right skewed with a long tail on the right.

Figure II: Histogram of standard deviations of daily % changes of DJIA: 1900-1999



Taking the natural log of monthly standard deviations reduces the deviation from normality as the Figure III below shows.

Figure III: Histogram of log of standard deviations of daily percentage changes of DJIA: 1900-1999



IV. ANALYSIS OF RESULTS

Month effect: Comparison of variances

For the entire data set, standard deviation of monthly percentage changes (Table 5) has ranged from 4.08% (for February) to 6.63% (for April). The standard deviations of the monthly percentage changes of January (4.63%), February (4.08%), and December (4.62%) are significantly lower than the standard deviations for the other months (p-values of F-test are between 0.00 and 0.01). The standard deviation of the monthly percentage changes of April (6.63%) is significantly higher than the standard deviations for the other months (p-value of F-test = 0.00). So for the whole century, April underwent the highest month-to-month volatility.

Table 5: % Change in DJIA from 1900 to 1999

Period 1900-1999	All	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	1196	100	100	100	100	100	100	100	99	99	99	99	100
Standard Deviation	5.48	4.63	4.08	5.15	6.63	5.39	5.36	5.53	5.96	5.87	5.94	5.85	4.62
p-value (F test)		0.011	0.000	0.197	0.004	0.426	0.389	0.455	0.119	0.160	0.132	0.180	0.011
Month Effect (Var)		Lower	Lower		Higher								Lower

The standard deviations of the monthly percentage changes for the first half of the last century (Table 6) shows a pattern somewhat similar to what we find for the entire data set: January and February experienced significantly lower variances and April experienced significantly higher variance compared to the other months.

Table 6: % Change in DJIA from 1900-1949

Period 1900-1949	All	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	596	50	50	50	50	50	50	50	49	49	49	49	50
Standard Deviation	6.58	4.09	4.71	6.66	8.57	6.79	6.83	6.79	6.62	7.37	6.64	6.85	5.90
p-value (F test)		0.000	0.001	0.479	0.006	0.397	0.374	0.394	0.485	0.137	0.490	0.365	0.154
Month Effect (Var)		Lower	Lower		Higher								

The first 25 years – 1900-1924 (Table 7) – shows only February exhibiting significantly lower variance (p value of F-test = 0.04) compared to the other months; no month shows significantly higher variance.

Table 7: % Change in DJIA from 1900-1924

Period 1900-1924	All	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	296	25	25	25	25	25	25	25	24	24	24	24	25
Standard Deviation	5.41	4.42	4.08	5.45	5.71	4.78	4.67	6.04	4.56	6.13	5.51	6.48	6.78
p-value (F test)		0.099	0.040	0.498	0.390	0.218	0.180	0.251	0.147	0.225	0.491	0.130	0.073
Month Effect (Var)			Lower										

The pattern of standard deviations of the monthly percentage changes for the second 25 years – 1925-1949 (Table 8) – closely resembles what we find for the entire data set: significantly lower for January, February and December, and significantly higher for April – compared to the rest of the months. The overall higher standard deviation for this sub-period compared to the first sub-period is possibly attributable to greater level of imperfect information which has been found to create excess volatility in asset returns (see Gerlach [2005]). The events during this period which could have led to a greater level of imperfect information arose from the Great Depression Years and the Second World War. A finding by Jones, Walker and Wilson (2004) indicate that large negative changes appear to influence investor behavior more than large positive changes. This sub-period experienced large negative changes more than positive changes which may have resulted in higher standard deviation compared to the other three quarters.

Table 8: % Change in DJIA from 1925-1949

Period 1925-1949	All	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	300	25	25	25	25	25	25	25	25	25	25	25	25
Standard Deviation	7.56	3.80	5.30	7.25	10.83	8.44	8.24	7.39	8.09	8.44	7.62	7.25	5.02
p-value (F test)		0.000	0.015	0.417	0.010	0.248	0.296	0.476	0.335	0.238	0.514	0.413	0.007
Month Effect (Var)		Lower	Lower		Higher								Lower

The second half of the last century (Table 9) shows significant month effect in terms of variance. Three months experienced significantly higher variances, and four significantly lower variances, compared to the other months. This was largely the effect of the last quarter of the century (Exhibit 11).

Table 9: % Change in DJIA from 1950-1999

Period 1950-1999	All	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	600	50	50	50	50	50	50	50	50	50	50	50	50
Standard Deviation	4.09	5.09	3.34	3.01	3.75	3.54	3.32	3.96	5.02	3.92	5.22	4.64	2.80
p-value (F test)		0.017	0.030	0.003	0.212	0.089	0.026	0.386	0.024	0.362	0.010	0.112	0.000
Month Effect (Var)		Higher	Lower	Lower			Lower		Higher		Higher		Lower

The third quarter of the last century roughly corresponds to the Breton Woods fixed exchange rate system. This sub-period was characterized by lower standard deviation of monthly changes which ranged from about 2.50% to 5.1% (Table 10). This range was the lowest of all the four quarters. The fixed exchange rate regime had a soothing effect on the volatility of the DJIA.

Table 10: % Change in DJIA from 1950-1974

Period 1950-1974	All	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	300	25	25	25	25	25	25	25	25	25	25	25	25
Standard Deviation	3.75	4.15	2.49	2.19	3.74	3.51	3.55	3.91	4.02	4.56	3.37	5.13	2.76
p-value (F test)		0.267	0.007	0.001	0.526	0.368	0.399	0.406	0.341	0.102	0.257	0.021	0.032
Month Effect (Var)			Lower	Lower								Higher	Lower

In addition to exchange rate stability, the third quarter also corresponded to more stable commodity prices and interest rates which led to lower volatility of stock prices. February, March and December experienced lower standard deviation compared to the other months; November experienced higher variance.

The breakdown of the Breton Woods system led to higher standard deviation in the last quarter which ranged from 2.8% to 6.6% (Table 11). Greater world-wide political upheavals may also have contributed to the higher overall standard deviation in the fourth quarter. Three months experienced higher volatility (January, August and October) and three months experienced lower variances compared to the other months ((June, September and December). An empirical question is the extent to which the increased volatility is associated with outliers, not the underlying processes of the market (see Gonzalez, Spencer and Walz [2003]).

Table 11: % Change in DJIA from 1975-1999

Period 1975-1999	All	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	300	25	25	25	25	25	25	25	25	25	25	25	25
Standard Deviation	4.40	5.73	3.99	3.70	3.74	3.40	2.77	4.06	5.94	3.24	6.62	4.16	2.88
p-value (F test)		0.039	0.274	0.136	0.159	0.055	0.003	0.315	0.024	0.032	0.004	0.383	0.006
Month Effect (Var)		Higher					Lower		Higher	Lower	Higher		Lower

If any consistent pattern emerges in terms of month effect with respect to variance, it is the following: in the first half of the last century, February saw lower variance compared to the rest of the months, and in the second half of the century, December saw lower variance. In the last quarter of the last century, variance changed gears from being higher in January, to lower in June, to higher in August, to lower in September, to higher in October, to lower in December –higher or lower compared to the other months and statistically significant. Hence we find a periodicity in case of variance in the last quarter.

The 1930s appear to have exhibited the highest monthly volatility (Table 12) – January's standard deviation was 4.48%, and for the other months it has ranged from 7.1% to 17.1% -- rather high when compared to the standard deviations of changes for the various months in other decades.[3] Monthly standard deviations decreased in the next three decades – the 1940s, 1950s and the 1960s. The standard deviation in those three decades ranged only from 2.0% to 4.5% except for May of the 1940s, which was adversely affected by a 21.7% decline in May of 1940. In the 1970s, standard deviation of monthly returns increased somewhat, ranging from 2.2% to 7.8%.[4] It ranged from 2.5% to 8.9% in the 1980s, and went down somewhat in the 1990s, ranging from 2.9% to 6.3%. Based on the range of the standard deviations of monthly returns, 1920s and 1930s seem to have exhibited higher monthly volatility than recent decades. It is not surprising given that 1930s and prior decades have suffered so many large monthly increases as well as decreases (Tables 2 and 3) which contributed significantly to volatility. In general, the variance effect was pronounced in the first six months of the year.

[3] Tables not presented for brevity.
[4] These findings are supported by past research. See Cochran, Heck and Shaffer (2003).

Table 12: % Change in DJIA from 1900-1999 (By Decade)

Period 1900-1999	All	1900-09	1910-19	1920-29	1930-39	1940-49	1950-59	1960-69	1970-79	1980-89	1990-99
Count	1196	120	116	120	120	120	120	120	120	120	120
Standard Deviation	5.48	5.38	5.63	5.71	10.34	4.12	3.29	3.62	4.60	4.72	3.98
p-value (F test)		0.403	0.345	0.264	0.000	0.000	0.000	0.000	0.004	0.012	0.000
Decade Effect (Var)					Higher	Lower	Lower	Lower	Lower	Lower	Lower

Democrat vs. Republican Effect

There were eleven Republican Presidents (spanning 53 years and 3 months) and seven Democratic Presidents (spanning 46 years 5 months) during the period 1900-1999 (the market was closed for four months in 1914). The variances of monthly percentage changes during the Republican years were significantly higher than during the Democratic years implying less consistency in monthly returns during Republican presidencies.[5]

Next, we present the analyses of monthly standard deviations of daily percentage changes.

V.2 Means of monthly standard deviations of daily percentage changes 1900 to 1999

The month-wise statistics for monthly standard deviations of daily percentage changes for the DJIA for the entire period (January 1900 to December 1999) are shown in Table 13.

Table 13: Standard Deviation of Daily % Change in DJIA from 1900 to 1999

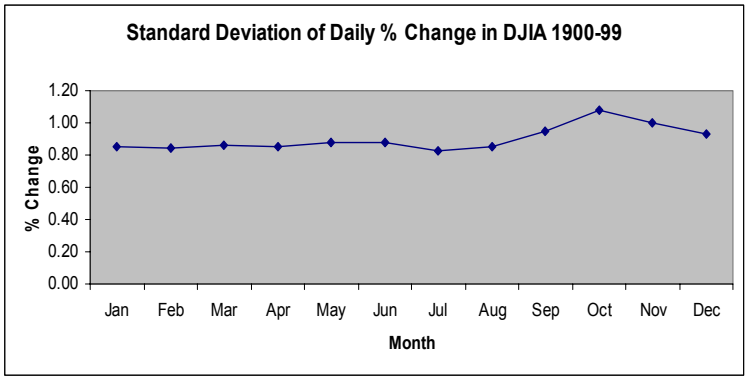
Period 1900-1999	All	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	1196	100	100	100	100	100	100	100	99	99	99	99	100
Mean of SD	0.90	0.85	0.85	0.86	0.85	0.88	0.87	0.83	0.86	0.95	1.08	1.00	0.93
p-value (F test)		0.000	0.002	0.081	0.000	0.016	0.038	0.000	0.007	0.321	0.000	0.058	0.000
Month Effect (Mean)											Higher		

The mean monthly standard deviations of daily percentage changes vary from a minimum of 0.83% for July to a maximum of 1.08% for October. The monthly standard deviations of daily percentage changes from 1900 to 1999 are shown in the graph below. Figure IV shows that volatility is at a slightly higher level during September to December

[5] Table not presented for brevity.

with a peak in October, which corresponds to popular notion and common market experience. However, October is a volatile month in terms of daily percentage changes. We saw earlier that standard deviation of monthly percentage changes (Table 5) has ranged from 4.08% (for February) to 6.63% (for April). February's mean of daily percentage change (0.85%) is on the low side, roughly corresponding to its lowest standard deviation in terms of monthly change.

Figure IV: Standard deviation of daily percentage change in DJIA: 1900-1999



1900-1949 vs. 1950-1999

Table 14 shows that the mean monthly standard deviation of daily percentage changes of 1.03% for 1900-1949 varies from a low of 0.93% for January and August to a high of 1.19% in October. No month experienced volatility significantly different from those of the other months.

Table 14: Standard Deviation of Daily % Change in DJIA from 1900 to 1949

Period 1900-1949	All	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	596	50	50	50	50	50	50	50	49	49	49	49	50
Mean of SD	1.03	0.93	0.96	1.00	0.97	1.01	1.01	0.94	0.93	1.10	1.19	1.16	1.13
p-value (F test)		0.000	0.081	0.376	0.013	0.053	0.236	0.020	0.040	0.382	0.000	0.057	0.000
Month Effect (Mean)													

The 50-year period is further sub-divided into two 25-year periods: 1900-1924 (Table 15) and 1925-1949 (Table 16). The mean monthly standard deviation of daily percentage changes at 0.93% for 1900-1924 is lower than 1.12% for 1925-1949 sub-period.

Exhibit 15: Standard Deviation of Daily % Change in DJIA from 1900 to 1924

Period 1900-1924	All	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	296	25	25	25	25	25	25	25	24	24	24	24	25
Mean of SD	0.93	0.91	0.91	0.86	0.87	0.95	0.85	0.86	0.86	0.93	0.96	1.00	1.22
p-value (F test)		0.000	0.091	0.382	0.000	0.415	0.002	0.006	0.209	0.004	0.013	0.085	0.000
Month Effect (Mean)													

The higher standard deviation of daily percentage changes in the second quarter may be attributable to the Great Depression years, and the Second World War. During 1900-1924, the means of monthly standard deviations of daily percentage changes varied between a low of 0.85% for June to a high of 1.22% for December.

Exhibit 16: Standard Deviation of Daily % Change in DJIA from 1925 to 1949

Period 1925-1949	All	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	300	25	25	25	25	25	25	25	25	25	25	25	25
Mean of SD	1.12	0.94	1.02	1.15	1.07	1.06	1.17	1.02	1.00	1.25	1.42	1.31	1.03
p-value (F test)		0.017	0.250	0.426	0.160	0.097	0.519	0.163	0.104	0.434	0.001	0.053	0.308
Month Effect (Mean)													

During 1925-1949, it ranged between a low of 0.94% for January to a high of 1.42% for October. So the phenomenon of jittery October can be traced back to the second quarter.

The mean of monthly standard deviations of daily percentage changes (0.77%) for the next fifty years – 1950-1999 (Table 17) – is much lower than the 1.03% for the first fifty years: 1900-1949.

Table 17: Standard Deviation of Daily % Change in DJIA from 1950 to 1999

Period 1950-1999	All	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	600	50	50	50	50	50	50	50	50	50	50	50	50
Mean	0.77	0.78	0.73	0.72	0.73	0.75	0.74	0.71	0.78	0.80	0.97	0.84	0.72
p-value (F test)		0.240	0.000	0.000	0.001	0.101	0.000	0.000	0.196	0.307	0.000	0.205	0.093
Month Effect (Mean)													

Thus, while the DJIA grew in magnitude, it became less volatile in terms of daily percentage changes during the second half of the last century. The mean monthly standard deviations of daily percentage changes ranged from a low of 0.71% for July to a high of 0.97% for October.

This 50-year period was also sub-divided into two 25-year sub-periods: 1950-1974 (Table 18) and 1975-1999 (Table 19).

Table 18: Standard Deviation of Daily % Change in DJIA from 1950 to 1974

Period 1950-1974	All	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	300	25	25	25	25	25	25	25	25	25	25	25	25
Mean of SD	0.67	0.60	0.61	0.58	0.58	0.70	0.72	0.68	0.68	0.72	0.74	0.76	0.63
p-value (F test)		0.044	0.003	0.004	0.001	0.010	0.347	0.151	0.334	0.153	0.046	0.209	0.384
Month Effect (Mean)				Lower	Lower								

During the first sub-period, 1950-1974, the overall mean monthly standard deviations of daily percentage changes was 0.67%, and ranged from a low of 0.58% for March and April to a high of 0.76% for November. With 0.74%, October was right behind. During the second sub-period, the standard deviation of daily changes increased to 0.88% compared to the previous quarter and ranged between a low of 0.75% for July to a high of 1.20% for October. So the jitteriness of October which can be traced back to the second quarter, continued through the third and fourth quarters. It was the highest in the last quarter followed by the second quarter. However, the mean standard deviation of daily percentage changes was higher in the first quarter (0.96%) compared to the third quarter (0.74%). (The mean standard deviation of daily percentage changes for October in the first quarter was third highest in that quarter.) The Breton Woods system seems to have contained the volatility in the third quarter.

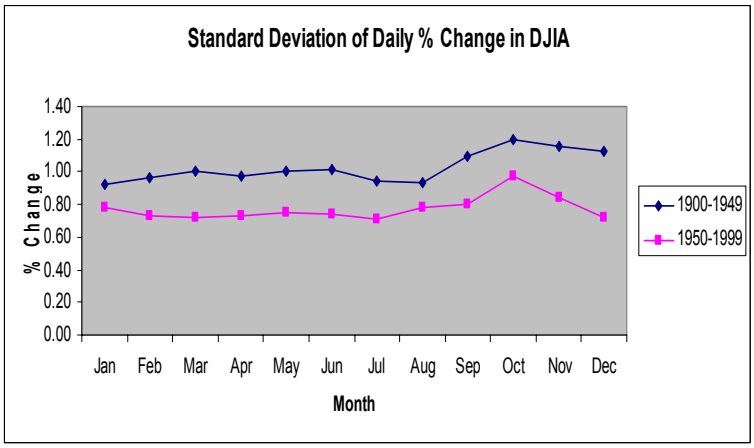
Table 19: Standard Deviation of Daily % Change in DJIA from 1975 to 1999

Period 1950-1999	All	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Count	300	25	25	25	25	25	25	25	25	25	25	25	25
Mean of SD	0.88	0.96	0.84	0.86	0.88	0.80	0.76	0.75	0.88	0.89	1.20	0.92	0.82
p-value (F test)		0.220	0.000	0.000	0.003	0.000	0.000	0.000	0.287	0.141	0.000	0.105	0.050
Month Effect (Mean)							Lower	Lower					

Figure V below shows an interesting contrast of the means of monthly standard deviations of daily percentage changes for 1900-1949 versus 1950-1999. Firstly, the trend lines have close correlation. Secondly, the volatility of daily percentage changes was lower during the second half of the century as compared to the first half. Thirdly, September to November have tended to experience higher volatility with the peak occurring in October. If we compare this graph with the earlier one for the entire data

period (1900-1999), we can see a striking similarity in all the three. If we compare the four 25-year sub-periods, the volatility has varied as follows: 0.93% during 1900-1925, 1.12% during 1925-1949, 0.67% during 1950-1974 and 0.88% during 1975-1999. As we can see, the stock market exhibited high volatility in the second quarter and unusually low volatility during the post-war years 1950-1974. This may partly be a result of the Breton Woods fixed exchange rate system that started in full-swing in 1945. The greater volatility of the 1975-1999 sub-period may partly be due to the break-down of that system, and the spill-over effect of increased volatility of commodities prices, exchange rates, interest rates, and greater information flows as we noted earlier.

Figure V: Standard deviation of daily percentage change in DJIA: 1900-1949 versus 1950-1999



Month effect: Comparison of the mean monthly standard deviation of daily percentage changes

We analyze if the mean of monthly standard deviations of daily percentage changes for a month was significantly different compared to the means of the other eleven months. For the 1900-1999 period (Table 13), the mean monthly standard deviation of daily percentage changes for October is the maximum at 1.08% and is significantly higher than the means of the other months (p value of t-test = 0.04). In other words, October has experienced the greatest day-to-day volatility compared to the other months of the year. October did not experience the highest volatility based on monthly percentage changes.

When we sub-divide the century into two periods: 1900-1949 (Table 14) and 1950-1999 (Table 17), the mean standard deviation of none of the months is found to be significantly different from those of the remaining months. Thus, we observe an October effect over the entire period but find no month effect if we look at the first and second halves of the last century separately. However, we must add that October exhibited the greatest volatility whether we look at the 1900-1999 period as a whole or sub-divide into two fifty year sub-periods (though not significant in these sub-periods). Thus, October can be considered to be the most volatile month out of the 12 months of the year based on mean of standard deviations of daily percentage changes.

We also did not find any significant month effect in terms of volatility when we subdivided the first half into two quarters: 1900-1924 (Table 15) and 1925-1949 (Table 16). For the period 1950-1999, though we found no significant month effect, we found significant month effects when we divide this period into two sub-periods: 1950-1974 (Table 18) and 1975-1999 (Table 19). During the third quarter – 1950-1974 – the mean monthly standard deviation of daily percentage changes was significantly lower for March and April when each of those was compared with the remaining months. During the fourth quarter: 1975-1999, June and July were found to have significantly lower volatility compared to remaining months of the year.

We did Kruskal-Wallis test for differences in the monthly medians of the standard deviations of daily percentage changes for the entire data (1900-1999). No significant differences in the medians were detected (Kruskal-Wallis H statistic = 11.63, and p value = 0.39). We also did nonparametric Mood's Median test which is more robust against outliers. This test also failed to support the October effect that we found for the entire data using t-test (the Mood's Median test Chi-square = 8.01, and p value = 0.71). But the medians of the daily percentage changes of the last three months of the year are among the highest: October: 0.7848, November: 0.8235, December: 0.6876.[6]

When we compare the means of standard deviations of monthly percentage changes that we found earlier with the standard deviations of daily percentage changes, the findings are somewhat similar as can be seen in Table 20.

[6] The detailed outputs of tests are not reported for brevity.

Table 20: Comparison between SDs of monthly and daily percentage changes

	Means of SDs of mo.% chg.	Means of SDs of daily % chg.
1900-1999	5.48%	0.90%
1900-1949	6.58	1.03%
1900-1924	5.41	0.93
1925-1949	7.56	1.12
1950-1999	4.09	0.77
1950-1974	3.75	0.67
1975-1999	4.40	0.88

The ups and downs in the two columns are similar. The first half of the century has higher standard deviation (it has seen the First World War, the Great Depression years, and the Second World War) compared to the second half (6.58% versus 4.09% based on means of standard deviations of monthly changes, and 1.03% versus 0.77% based on means of standard deviations of daily changes). The third quarter (1950-1974) has the lowest standard deviation which may be attributable to the Breton Woods fixed exchange rate system. The breakdown of that system corresponds to increase in the standard deviation of monthly returns (from 3.75% to 4.40%). Apart from the break-down of the Breton-Woods system of fixed exchange rate system after 1972, the world saw the onset of a volatile period in terms of commodity prices, interest rates, and exchange rates. The increase is also partly attributable to the greater and quicker flow of information as a result of advances in information technology, greater trading as a result of creation of more mutual funds and investments by individual investors. Also, lower cost of information, ability to trade faster, larger quantity and frequency of trading have increased volatility in the last quarter compared to the third quarter, but not compared to the first two quarters. An empirical question is if the higher volatility in the second and fourth quarters may be a consequence of higher equity premium. Kim, Morley and Nelson (2004) find support for a positive relationship between stock market volatility and the equity premium. Another empirical question is the relationship of the higher volatilities to insider trading. Du and Shang-Jin (2004) find that countries with more prevalent insider trading have more volatile stock markets, even after one controls for liquidity/maturity of the market, and the volatility of the underlying fundamentals.

The consequence of investors getting more experienced, and the stock markets getting more developed, and the availability of risk management instruments and the

scope for international investing might possibly have created lower volatility than what would have been otherwise. So it appeared that the stock market became more volatile in recent times – but that was in terms of points, not in percentage terms.

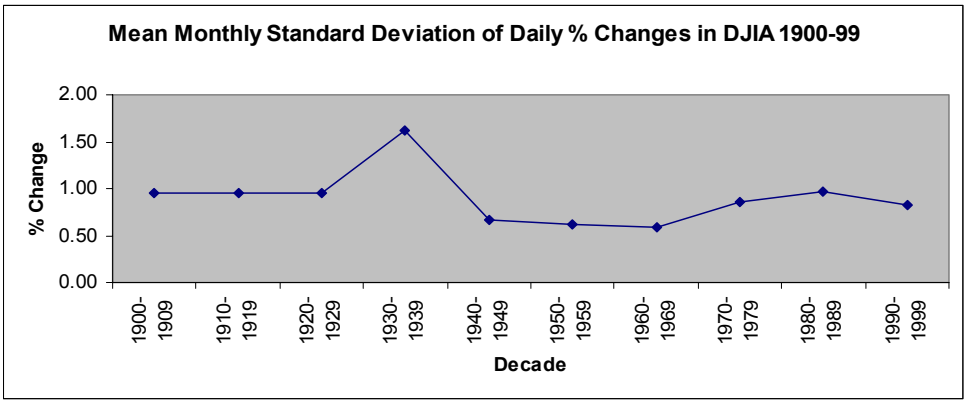
Also, in terms of means of standard deviations of daily percentage changes, it has been more volatile in the first two quarters then in the last quarter even though the perception may be different.

No significant differences existed at 5% level in the means of standard deviations of monthly changes between the different sets of the four quarters (Quarter 1 versus Quarter 2 Quarter 1 versus Quarter 3, Quarter 1 versus Quarter 4, etc.). Using t-test, we find difference between Quarters 1 and 4 but at 9% level and between Quarters 3 and 4 at 8% level. Analysis of variance yields an F-statistic of 1.11 ($p = 0.35$) exhibiting no difference between the means of standard deviations of monthly changes of the four quarters. We get similar conclusion from nonparametric Kruskal-Wallis test ($p = 0.35$) and Mood's Median test (0.38). The means of standard deviations of daily changes between different sets of quarters were significantly different ($p = 0.00$) except for Quarters 1 and 4 ($p = 0.21$). Kruskal-Wallis as well as Mood's Median tests show at least for one of the quarters the means of standard deviations of daily changes were significantly different compared to those of the other quarters. Analysis of variance also yield similar result (F-statistic = 35.00, $p = 0.00$). So the differences between quarters were more pronounced in terms of volatility of daily changes.

V.3 Volatility through the decades

If we divide the data for the last century into decades, we can get some interesting historical overview as shown in Figure VI. The mean of monthly standard deviations of daily percentage changes were between a low of 0.59% during 1960-1969 to a high of 1.61% during 1930-1939. Thus, the thirties stand out as the most volatile period in terms of daily percentage changes followed by 1980-1989 as a distant second with a mean of monthly standard deviations of daily percentage changes of 0.97%. We have roughly similar patterns based on standard deviations of monthly percentage changes.

Figure VI: Decade-wise mean monthly SD of daily % changes



V. SUMMARY AND CONCLUSION

We have explored if the variance of the monthly percentage changes for a month during a period was different from the variances of all the other months in that period. For the 100 years of data in our study, we find that the month effect with respect to standard deviation of monthly percentage changes is found for January, February and December (lower variances), and April (higher variance). The first half of the century had lower standard deviation of monthly changes compared to the second half.

The mean of monthly standard deviations of daily percentage changes for the twelve months exhibit a slightly rising trend, peaking in October and are all significantly different from zero. While the DJIA grew in magnitude, it became less volatile in terms of daily percentage changes during the second half of the last century compared to the first half. For the 1900-1999 period, the mean monthly standard deviation of daily percentage changes for October (1.08%) was the maximum and also significantly higher than the means of the other months ($p = 0.04$). In other words, October has experienced the greatest day-to-day volatility compared to the other months of the year. However, non-parametric Kruskal-Wallis test as well as Mood's Median test does not find any significant difference in the monthly medians of daily percentage changes.

So it appears that the stock market has become more volatile in recent times – but that was in terms of points, not in percentage terms. If we divide the data for the last century into decades, the thirties stand out as the most volatile period in terms of monthly or daily percentage changes followed by 1980-1989 as a distant second.

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