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An investigation of duration dependence in the American stock market cycle

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This paper investigates the duration dependence of the US stock market cycles. A new classification method for bull and bear market regimes based on the crossing of the market index and its moving average is proposed. We show evidence of duration dependence in whole cycles. The half cycles, however, are found to be duration independent. More importantly, we find that the degree of duration dependence of the US stock market cycles has dropped after the launch of the NASDAQ index.

Keywords: duration dependence; stock market cycles; moving average

JEL: C41, G19, C10

1. Introduction

Previous studies on duration dependence focus on business cycles. For example, Diebold and Rudebusch [4,5] investigate the duration properties of American business cycles. It is shown that expansions and contractions are duration independent while the whole cycles are not. Sichel [16] finds positive duration dependence for expansions before World War II and for contractions after World War II. Durland and McCurdy [6] find evidence of duration dependence for contractions. The duration of a business cycle can be very long. A complete cycle of expansion and contraction usually lasts for a decade or even longer. As a result, the number of observations available for duration analysis is rather limited, and tests for duration dependence cannot be reliably conducted. In this paper, we examine the duration dependence of the US stock market cycles. The cyclicality of the US stock market has long been observed.[1] Stock market cycles are similar to business cycles in nature but are much shorter in duration. A complete stock market cycle normally takes less than 4 years. As a result, more observations can be obtained for duration analysis.

To study the duration dependence of stock market cycles, a lucid definition of cycles is needed. In the literature, there is no general consensus on the definition of stock market cycles. Earlier studies,

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including Fabozzi and Francis [7], Kim and Zumwalt [9], and Chen [3], define expansions as the periods when the monthly returns exceed a certain value. Such a definition ignores the existence of price trends. Lunde and Timmermann [11] define an expansion as a long-term upward price movement characterized by higher intermediate highs interrupted by higher intermediate lows. Pagan and Sossounov [14] use a BB-type definition[2] [2] to classify market regimes. A stock market is said to change from contraction to expansion if the stock index has risen for a substantial period since its previous troughs.

A common method for identifying the bull/bear regime is the crossing of the 250-day moving average line. A bull (bear) regime is the period during which the stock index is above (below) its 250-day moving average.[3] Under this definition, an average investor who has taken a long position in the previous year has made a profit (loss) in a bull (bear) market, and so the market sentiment will be good (bad). There are three advantages of this classification method over the existing BB method. First, it is easy to implement. Second, it can self adjust for price trends. Third, it can quickly identify the market regime.[4]

In this paper, the nonparametric tests of Diebold and Rudebusch [4] for duration dependence are applied to the Dow Jones industrial average index and the NASDAQ composite index. We find evidence of duration dependence in whole cycles. The half cycles, however, are found to be duration independent. To examine the duration dynamics, we also conduct an analysis for structural change in duration dependence over time. It is found that the degree of duration dependence of the US stock market cycles has dropped after the launch of the NASDAQ.[5]

The remainder of this paper is organized as follows: Section 2 introduces the tests for duration dependence. Section 3 analyzes the data and presents the summary statistics of the American stock market cycles. Section 4 presents the empirical results and Section 5 concludes the paper.

2. Tests for duration dependence

A key element in the test of duration dependence is the hazard rate, which is the ending probability of a given state.[6] Negative (positive) duration dependence occurs when the hazard rate declines (increases) with the length of a phase.[7] In an efficient market where the stock index follows a random walk, the termination probability of the existing state should not depend on the duration of the state. An immediate implication of the existence of duration dependence is the rejection of the random walk hypothesis.

2.1 *W and* $W(t_0 = a)$ *tests*

Consider a general hazard function, denoted by $\lambda(t)$, which measures the conditional probability that a process will end after a duration of length t. We would like to test the hypothesis that there is no duration dependence in the U.S. stock market cycles,[8] which is equivalent to test whether the hazard function $\lambda(t)$ is a constant. More precisely, we test the following hypothesis as follows:

$$H_0 : \lambda(t) = \lambda, \text{ for } t \geq 0,$$

where t is the length of the duration. The hazard function $\lambda(t)$ provides a complete characterization of the unconditional density of the length of duration $f(t)$ as:

$$f(t) = \lambda(t) \exp\left(-\int_0^t \lambda(u)\mathrm{d}u\right).$$

The constant hazard function $\lambda(t) = \lambda$ implies an exponential distribution of the duration, i.e., $f(t) = \lambda \exp(-\lambda t), t \geq 0$.[9] Consequently, the test for duration independence is equivalent to a test of whether the spells of expansion and contraction are generated by an exponential distribution. The above null hypothesis can therefore be rewritten as

$$H_0 : f(t) = \lambda \exp[-\lambda(t - t_0)], \quad t \geq t_0, \quad \lambda, \quad t_0 \quad \text{unknown}, \tag{1}$$

where t_0 is the minimum maturity of phases.[10] Following Diebold and Rudebusch [4], the tests of Shapiro and Wilk [17] are employed. We rearrange the durations in an ascending order ($t_1 \leq t_2 \leq \cdots \leq t_N$) and define

$$W = \frac{(\bar{t} - t_1)^2}{(N-1)\hat{\sigma}^2}, \tag{2}$$

where $\bar{t} = \sum_{i=1}^{N} t_i/N$ and $\hat{\sigma}^2 = \sum_{i=1}^{N}(t_i - \bar{t})^2/N$.

Under the null hypothesis, the distribution of W is invariant to the true values of λ and t_0. The finite-sample critical values of W for $N = 3$ to $N = 100$ are tabulated in [17].[11] If the value of W exceeds the critical value, we reject the null hypothesis of duration independence. To test H_0 with a prespecified minimum duration $t_0 = a$, the modified W statistic of Stephens [18] is used. The null hypothesis becomes

$$H_0' : f(t) = \lambda \exp[-\lambda(t - a)], \quad t \geq a, \quad \lambda \text{ unknown}, \quad a \text{ known}. \tag{3}$$

The corresponding statistic is

$$W(t_0 = a) = \frac{A^2}{N[(N+1)B - A^2]}, \tag{4}$$

where $A = \sum_{i=1}^{N}(t_i - a)$ and $B = \sum_{i=1}^{N}(t_i - a)^2$. The statistic $W(t_0 = a)$ for a sample of size N and the statistic W for a sample of size $N + 1$ have the same distribution.

2.2 *Z and Z ($t_0 = a$) tests*

To examine the robustness of our results, we also conduct the test of Brain and Shapiro [1]. Let

$$Z = \frac{\sum_{i=1}^{N-1} \tilde{i}\hat{Y}_{i+1}}{\sum_{i=1}^{N-1} Y_{i+1}\left[\sum_{i=1}^{N-1} \tilde{i}^2/N(N-1)\right]^{1/2}}, \tag{5}$$

where $\tilde{i}$ and $\hat{Y}_i$ are the 'de-meaned' variables, $\tilde{i} = i - (N/2)$ and $\hat{Y}_i = Y_i - \bar{Y}$, respectively. Y_i is the normalized spacing between the ordered durations defined as

$$Y_i = (N - i + 1)(t_i - t_{i-1}), \quad i = 2, \ldots, N. \tag{6}$$

Under the null hypothesis, Brain and Shapiro [1] show that Z statistic is asymptotically standardized normal. Similarly, a prespecified minimum duration $t_0 = a$ can also be imposed. The modified statistic is denoted by $Z(t_0 = a)$, which also has an asymptotic standardized normal distribution.

3. Data

The two major US stock indices, namely, the Dow Jones industrial average index and the NASDAQ composite index, are analyzed. The corresponding moving averages are computed. The sample period of the Dow Jones industrial average index is from 1 October 1928 to 3 April 2006. The bull and bear markets are defined by comparing the monthly index with its 12-month moving average

(12MMA). The period where the index exceeds its 12MMA is a bull market. Otherwise, it is a bear market. A phase is designated only if it has achieved a certain maturity. Following Pagan and Sossounov [14], a minimum duration of 4 months is imposed on half cycles.[12] Given the half cycles, the bull-to-bear (bear-to-bull) whole cycle is defined as the duration from the start of a bull (bear) phase to the end of a bear (bull) phase. Table 1 presents the bull and bear markets and their corresponding durations.[13] The last two columns in Table 1 show the durations in months for the bear-to-bull and bull-to-bear whole cycles. Table 2 reports the summary statistics of each duration sample in Table 1.[14]

We also examine the weekly NASDAQ composite index from 8 February 1971 to 27 March 2006. The history of NASDAQ is much shorter than that of the Dow Jones. In order to generate sufficient duration data, we compare the weekly index with its previous 26-week moving average (26WMA).[15] The period where the index exceeds its previous 26WMA is identified as a bull market. Otherwise, it is a bear market. The minimum duration for half cycles is set to eight weeks. Table 3 presents the bull and bear markets and their corresponding durations. Table 4 provides the summary statistics of the duration data in Table 3.

Table 1. Bull and bear markets turning dates and durations (months) (Dow Jones industrial average index).

Turning dates	Bear	Turning dates	Bull	Bear-to-bull	Bull-to-bear
1 October 1929 to 1 March 1933	42	3 April 1933 to 2 April 1934	13	55	19
1 May 1934 to 1 October 1934	6	1 November 1934 to 3 May 1937	31	37	44
1 June 1937 to 1 June 1938	13	1 July 1938 to 1 February 1939	8	21	14
1 March 1939 to 1 Augsut 1939	6	1 September 1939 to 1 April 1940	8	14	36
1 May 1940 to 3 August 1942	28	1 September 1942 to 1 July 1946	47	75	58
1 August 1946 to 2 June 1947	11	1 July 1947 to 1 October 1948	16	27	25
1 November 1948 to 1 July 1949	9	1 August 1949 to 2 March 1953	44	53	51
1 April 1953 to 1 October 1953	7	2 November 1953 to 1 August 1956	34	41	41
4 September 1956 to 1 March 1957	7	1 April 1957 to 1 July 1957	4	11	14
1 August 1957 to 1 May 1958	10	2 June 1958 to 1 December 1959	19	29	31
4 January 1960 to 1 December 1960	12	3 January 1961 to 1 March 1962	15	27	22
2 April 1962 to 1 October 1962	7	1 November 1962 to 1 April 1966	42	49	52
2 May 1966 to 1 February 1967	10	1 March 1967 to 1 May 1969	27	37	44
2 June 1969 to 1 October 1970	17	2 November 1970 to 2 January 1973	27	44	51
1 February 1973 to 2 January 1975	24	3 February 1975 to 1 December 1976	23	47	41
3 January 1977 to 1 June 1978	18	3 July 1978 to 4 September 1979	15	33	22
1 October 1979 to 1 April 1980	7	1 May 1980 to 1 June 1981	14	21	27
1 July 1981 to 1 July 1982	13	2 August 1982 to 3 January 1984	18	31	24
1 February 1984 to 2 July 1984	6	1 Aug 1984 to 1 September 1987	38	44	49
1 October 1987 to 1 August 1988	11	1 September 1988 to 2 July 1990	23	34	28
1 August 1990 to 3 December 1990	5	2 January 1991 to 3 January 2000	109	114	148
1 February 2000 to 1 April 2003	39	1 May 2003 to 3 April 2006	36	75	NA

Table 2. Summary statistics of bull and bear markets (months) (Dow Jones industrial average index).

Sample	Sample size	Mean duration	Standard error	Minimum duration
Bear markets	22	14	10.4	5
Bull markets	22	27.8	21.9	4
Bear-to-bull	22	41.8	23.2	11
Bull-to-bear	21	40.0	28.1	14

Table 3. Bull and bear markets turning dates and durations (weeks) (NASDAQ composite index).

Turning dates	Bull	Turning dates	Bear	Bull-to-bear	Bear-to-bull
9 August 1971 to 28 August 1972	56	5 September 1972 to 23 October 1972	8	64	20
30 October 1972 to 15 January 1973	12	22 January 1973 to 30 December 1974	102	114	132
6 January 1975 to 28 July 1975	30	4 August 1975 to 29 December 1975	22	52	167
5 January 1976 to 9 October 1978	145	16 October 1978 to 15 January 1979	14	159	72
22 January 1979 to 25 February 1980	58	3 March 1980 to 12 May 1980	11	69	76
19 May 1980 to 10 August 1981	65	17 August 1981 to 16 August 1982	53	118	110
23 August 1982 to 19 September 1983	57	26 September 1983 to 23 July 1984	44	101	148
30 July 1984 to 21 July 1986	104	28 July 1986 to 29 December 1986	23	127	63
5 January 1987 to 5 October 1987	40	12 October 1987 to 22 February 1988	20	60	54
29 February 1988 to 17 October 1988	34	24 October 1988 to 27 December 1988	10	44	52
3 January 1989 to 16 October 1989	42	23 October 1989 to 7 May 1990	29	71	40
14 May 1990 to 23 July 1990	11	30 July 1990 to 7 January 1991	24	35	90
14 January 1991 to 13 April 1992	66	20 April 1992 to 31 August 1992	20	86	101
8 September 1992 to 21 March 1994	81	28 March 1994 to 8 August 1994	20	101	119
15 August 1994 to 1 July 1996	99	8 July 1996 to 3 September 1996	9	108	109
9 September 1996 to 3 August 1998	100	10 August 1998 to 26 October 1998	12	112	87
2 November 1998 to 3 April 2000	75	10 April 2000 to 19 November 2001	84	159	94
26 November 2001 to 28 January 2002	10	4 February 2002 to 4 November 2002	40	50	116
11 November 2002 to 19 April 2004	76	26 April 2004 to 11 October 2004	25	101	46
18 October 2004 to 7 March 2005	21	14 March 2005 to 16 May 2005	10	31	55
23 May 2005 to 27 March 2006	45		NA	NA	NA

Table 4. Summary statistics of bull and bear markets (weeks) (NASDAQ composite index).

Sample	Sample size	Mean duration	Standard error	Minimum duration
Bear markets	20	29.0	25.2	8
Bull markets	21	58.4	35.0	10
Bear to bull	20	87.6	38.3	20
Bull to bear	20	88.1	38.0	31

Table 5. The test statistics and the corresponding p-values.

Dow Jones								
Regime\test	W ($t_0 = 3$)	W ($t_0 = 4$)	W ($t_0 = 5$)	W	Z ($t_0 = 3$)	Z ($t_0 = 4$)	Z ($t_0 = 5$)	Z
Bear	0.048 (0.960)	0.040 (0.609)	0.033 (0.279)	0.037 (0.403)	−0.372 (0.710)	0.347 (0.729)	1.23 (0.220)	0.931 (0.352)
	W ($t_0 = 2$)	W ($t_0 = 3$)	W ($t_0 = 4$)	W	Z ($t_0 = 2$)	Z ($t_0 = 3$)	Z ($t_0 = 4$)	Z
Bull	0.057 (0.757)	0.055 (0.819)	0.051 (0.950)	0.059 (0.796)	−1.36 (0.173)	−1.11 (0.266)	−0.841 (0.400)	−1.29 (0.196)
	W ($t_0 = 9$)	W ($t_0 = 10$)	W ($t_0 = 11$)	W	Z ($t_0 = 9$)	Z ($t_0 = 10$)	Z ($t_0 = 11$)	Z
Bear to bull	0.083 (0.102)	0.079 (0.155)	0.074 (0.228)	0.088 (0.114)	−1.91 (0.056)	−1.73 (0.083)	−1.54 (0.123)	−2.05 (0.041)*[a]
	W ($t_0 = 12$)	W ($t_0 = 13$)	W ($t_0 = 14$)	W	Z ($t_0 = 12$)	Z ($t_0 = 13$)	Z ($t_0 = 14$)	Z
Bull to bear	0.045 (0.739)	0.042 (0.615)	0.039 (0.490)	0.045 (0.645)	−0.700 (0.484)	−0.454 (0.650)	−0.188 (0.851)	−0.601 (0.548)
NASDAQ								
Regime\test	W ($t_0 = 6$)	W ($t_0 = 7$)	W ($t_0 = 8$)	W	Z ($t_0 = 6$)	Z ($t_0 = 7$)	Z ($t_0 = 8$)	Z
Bear	0.040 (0.448)	0.037 (0.330)	0.034 (0.212)	0.039 (0.339)	0.586 (0.558)	0.938 (0.348)	1.32 (0.186)	1.03 (0.304)
	W ($t_0 = 8$)	W ($t_0 = 9$)	W ($t_0 = 10$)	W	Z ($t_0 = 8$)	Z ($t_0 = 9$)	Z ($t_0 = 10$)	Z
Bull	0.090 (0.097)	0.087 (0.124)	0.084 (0.154)	0.101 (0.071)	−1.51 (0.130)	−1.39 (0.162)	−1.27 (0.204)	−1.77 (0.077)
	W ($t_0 = 18$)	W ($t_0 = 19$)	W ($t_0 = 20$)	W	Z ($t_0 = 18$)	Z ($t_0 = 19$)	Z ($t_0 = 20$)	Z
Bear to bull	0.142 (<0.01)**	0.138 (<0.01)**	0.135 (<0.01)**	0.172 (<0.01)**	−2.56 (0.011)*[a]	−2.49 (0.013)*	−2.42 (0.016)*	−3.03 (<0.01)**
	W ($t_0 = 29$)	W ($t_0 = 30$)	W ($t_0 = 31$)	W	Z ($t_0 = 29$)	Z ($t_0 = 30$)	Z ($t_0 = 31$)	Z
Bull to bear	0.108 (0.046)*	0.105 (0.052)	0.102 (0.066)	0.125 (0.026)*	−1.81 (0.071)	−1.72 (0.086)	−1.62 (0.105)	−2.16 (0.030)*

Notes: The values in parentheses are p-values, which are obtained by linearly interpolating the tables in [17].
[a]A negative value of Z implies positive duration dependence.
* p-value < 0.05.
** p-value < 0.01.

Table 6. The test statistics and the corresponding p-values.

Subsample 1: Dow Jones from October 1928 to February 1971								
Regime\test	W ($t_0 = 0$)	W ($t_0 = 1$)	W ($t_0 = 2$)	W	Z ($t_0 = 0$)	Z ($t_0 = 1$)	Z ($t_0 = 2$)	Z
Bear	0.062 (0.181)	0.046 (0.787)	0.033 (0.569)	0.037 (0.705)	−1.95 (0.051)	−0.906 (0.365)	0.543 (0.588)	0.223 (0.823)
	W ($t_0 = 0$)	W ($t_0 = 1$)	W ($t_0 = 2$)	W	Z ($t_0 = 0$)	Z ($t_0 = 1$)	Z ($t_0 = 2$)	Z
Bull	0.045 (0.745)	0.038 (0.943)	0.031 (0.582)	0.035 (0.681)	−0.678 (0.498)	0.050 (0.960)	0.927 (0.354)	0.636 (0.525)
	W ($t_0 = 2$)	W ($t_0 = 3$)	W ($t_0 = 4$)	W	Z ($t_0 = 2$)	Z ($t_0 = 3$)	Z ($t_0 = 4$)	Z
Bear to bull	0.074 (0.055)	0.066 (0.125)	0.059 (0.264)	0.067 (0.155)	−1.86 (0.063)	−1.46 (0.144)	−1.01 (0.315)	−1.42 (0.155)
	W ($t_0 = 3$)	W ($t_0 = 4$)	W ($t_0 = 5$)	W	Z ($t_0 = 3$)	Z ($t_0 = 4$)	Z ($t_0 = 5$)	Z
Bull to bear	0.073 (0.062)	0.065 (0.139)	0.057 (0.345)	0.065 (0.182)	−1.78 (0.075)	−1.35 (0.178)	−0.852 (0.394)	−1.26 (0.208)
Subsample 2: Dow Jones from February 1971 to April 2006								
Regime\test	W ($t_0 = 0$)	W ($t_0 = 1$)	W ($t_0 = 2$)	W	Z ($t_0 = 0$)	Z ($t_0 = 1$)	Z ($t_0 = 2$)	Z
Bear	0.070 (0.353)[a]	0.051 (0.944)[a]	0.034 (0.332)	0.038 (0.436)	−1.56 (0.118)[a]	−0.416 (0.677)[a]	1.27 (0.204)	0.983 (0.354)
	W ($t_0 = 0$)	W ($t_0 = 1$)	W ($t_0 = 2$)	W	Z ($t_0 = 0$)	Z ($t_0 = 1$)	Z ($t_0 = 2$)	Z
Bull	0.051 (0.944)[a]	0.044 (0.771)	0.037 (0.464)	0.042 (0.602)	−0.581 (0.561)[a]	0.014 (0.989)[a]	0.720 (0.472)[a]	0.387 (0.699)[a]
	W ($t_0 = 2$)	W ($t_0 = 3$)	W ($t_0 = 4$)	W	Z ($t_0 = 2$)	Z ($t_0 = 3$)	Z ($t_0 = 4$)	Z
Bear to bull	0.074 (0.228)[a]	0.066 (0.477)[a]	0.059 (0.695)[a]	0.068 (0.528)[a]	−1.33 (0.184)[a]	−0.937 (0.349)[a]	−0.494 (0.622)[a]	−0.918 (0.358)[a]
	W ($t_0 = 2$)	W ($t_0 = 3$)	W ($t_0 = 4$)	W	Z ($t_0 = 2$)	Z ($t_0 = 3$)	Z ($t_0 = 4$)	Z
Bull to bear	0.082 (0.174)[a]	0.073 (0.384)[a]	0.065 (0.614)[a]	0.077 (0.385)[a]	−1.51 (0.132)[a]	−1.14 (0.253)[a]	−0.734 (0.463)[a]	−1.19 (0.234)[a]

Notes: The values in parentheses are p-values, which are obtained by linearly interpolating the tables in [17].

[a] p-Value in subsample 2 is larger than its counterpart in subsample 1. A p-value higher than 0.05 suggests that the null hypothesis of duration independence cannot be rejected.

4. Results

Table 5 reports the test statistics and the corresponding p-values. The p-value is the likelihood of obtaining the observed test statistic under the null hypothesis of duration independence. A small p-value indicates a significant departure from exponentiality. The results of the Z tests are in solid agreement with those of the W tests. For half cycles, the hypothesis of duration independence cannot be rejected at conventional significance levels. Some evidence of duration dependence in whole cycles is found. To check the robustness of the results, we also perform the W $(t_0 = \gamma)$ and Z $(t_0 = \gamma)$ tests. The values in the third column of each table are obtained by letting the minimum duration to be the shortest observed duration.[16] The test values in the first two columns of each table are obtained with smaller t_0 values. The results of the Z $(t_0 = \gamma)$ tests are in accord with those of the W $(t_0 = \gamma)$ tests. For NASDAQ, the whole cycles exhibit duration dependence and most half cycles are duration independent. The duration property of the whole cycle may not be related to that of the half cycles.[17] Duration dependence in whole cycles suggests that the spell of the whole cycle (bear-to-bull markets or bull-to-bear markets) clusters around a certain duration and exhibits stochastic periodicity. For the Dow Jones industrial average, the bear-to-bull whole cycle clusters around 42 months. For the NASDAQ composite, the whole cycles cluster around 88 weeks.

To test whether there is a structural change of duration dependence in the US stock market, we split the Dow Jones sample into two parts, using the launching date of the NASDAQ index (i.e., February 1971) as the cut-off point. In order to make a consistent comparison between the Dow Jones and the NASDAQ, we employ the 6-month moving average rule with a minimum duration of 2 months to generate the duration data for the two Dow Jones subsamples.[18] The p-values of the tests for the first and second subsamples are given in Table 6. Note that the p-values in subsample 1 are smaller than their counterparts in subsample 2. A high p-value is in favor of the null hypothesis. Thus, the Dow Jones index has become more duration independent after the launch of the NASDAQ. From Table 6, the p-values for the Dow Jones index are generally larger than those for the NASDAQ index, indicating that the former market is less periodic and more efficient than the latter. A plausible explanation is that the Dow Jones index has a long history and consists of companies from a wide range of industries, while the NASDAQ mainly includes technological companies, which are subject to similar risks and have similar cyclical behavior.

5. Conclusion

In this paper, we analyze the duration dependence of the US stock market cycles, which has been a topic of increasing interest in recent years. Our paper contributes to the understanding of stock market cycles in three aspects. First, a new definition of stock market cycles is introduced. Unlike conventional classification methods, our definition avoids visual inspections of the market peaks and troughs and provides an unambiguous classification of market regimes. Second, we conduct four different nonparametric tests to examine the duration dependence of the US stock market cycles. A noticeable advantage of our tests is that they do not need any parametric assumptions. In essence, we find little evidence of duration dependence for half cycles, while some evidence for the whole cycles of the NASDAQ index and for the bear-to-bull cycles of the Dow Jones index is found. We also show that the NASDAQ index demonstrates a higher degree of periodicity comparing to the Dow Jones. Finally, our results have a significant implication for the efficient market hypothesis. Two subsamples of the Dow Jones index, using the launching date of the NASDAQ index as the cut-off point, are compared. It is found that the degree of duration dependence of the Dow Jones index is lower in the second subsample. This provides indirect evidence that the efficiency of the US stock market has improved after the establishment of the NASDAQ market.

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Notes

1. For instance, during the entire twentieth century, every mid-decade year that ended in a '5' (1905, 1915, 1925, etc.) was a profitable year. This pattern is unlikely a mere fluke. Pundits have attempted to correlate these cycles with events such as the presidential election and the decisions of the Federal Reserve Board on interest rates.
2. The BB algorithm suggests that, for any stock index, there is a peak at t if $P_t = \max\{P_{t-6}, \dots, P_{t-1}, P_t, P_{t+1}, \dots, P_{t+6}\}$, and there is a trough at t if $P_t = \min\{P_{t-6}, \dots, P_{t-1}, P_t, P_{t+1}, \dots, P_{t+6}\}$, where P_t denotes the value of the stock index at time t.
3. The use of 'bull' and 'bear' to describe markets comes from the way these two animals attack their opponents. In general, if the price trend is up, it is a bull market. If the trend is down, it is a bear market. Bull markets are characterized by optimism, investor confidence and expectations that strong results will continue. The opposite holds for bear market. See also the definition of bull-bear line in http://en.wikipedia.org/wiki/bull-bear_line.
4. In comparison, the BB type method has a time lag problem since it uses the future price to define the current trough and peak. For instance, if monthly data are used, we can only identify a regime 6 month after its occurrence.
5. Our results are useful for investors who would like to better manage their portfolios and for firms to determine a suitable time to launch their IPOs [8,10].
6. For example, the expansion or contraction of business cycles, the bull or bear phase of stock markets, the duration of unemployment of an individual.
7. McQueen and Thorley [12] show that the existence of speculative bubbles implies negative duration dependence in bull market. Stivers and Sun [19] demonstrate that the existence of momentum profits under negative duration dependence of market cycles.
8. The duration dependence of stock market cycles is related to a weak definition of periodicity. A variable X_t exhibits *deterministic strong periodicity* of period T if $X_{t+T} = X_t$, for all t. As far as the stock market is concerned, a weaker form is more relevant. A *deterministic bear-to-bull (bull-to-bear) weak periodicity* of period T is said to exist, if, for every t such that X_t is the beginning of a bear (bull) market, X_{t+T} will be the end of the subsequent bull (bear) market. A variable X_t exhibits *stochastic strong periodicity* of period T if $\mathrm{Corr}(X_t, X_{t+T})$ is high for all t. A series displays *stochastic bear-to-bull (bull-to-bear) weak periodicity* of period T if, for every X_t that is the beginning of a bear (bull) market, $X_{t+\tau}$ is the end of the following bull (bear) market, where τ is a random variable with mean T and a small variance σ^2. It is precisely the stochastic weak form of periodicity that we shall test in this paper.
9. We assume that time is continuous in our paper. In the discrete-time case, we may allow for geometric distribution.
10. The minimum maturity criterion of phases is imposed to avoid phantom phases due to temporary price fluctuations.
11. For the power performance of the tests, one is referred to Shapiro and Wilk [17], Brain and Shapiro [1], Stephens [18], and Samanta and Schwarz [15].
12. To check the robustness of our results to the choice of the minimum duration, we have also examined 3-month and 5-month minimum durations, and reached a similar conclusion.
13. We have also examined the centered 12-month moving average, i.e., the average of the previous and the following 6 months. However, the results show that many cycles are too short to be useful since the current stock price is very close to the centered moving average.
14. Comparing our Table 1 with Table 6 of Ohn *et al*. [13], for the 777 months in which the two data sets are overlapped (October 1929 to June 1994), 621 months (about 80%) share the same market regime. Thus, our moving average approach identifies regimes that correspond closely to standard perceptions of bull and bear markets. We also apply our test to their data and reach a similar conclusion.
15. Under the null hypothesis of duration independence, the window size of the moving average will not affect the test results as the number of observations goes to infinity.
16. For example, for the Dow Jones index, the minimum durations are 5 months for bear markets, 4 months for bull markets, 11 months for bear-to-bull cycles, and 14 months for bull-to-bear cycles.
17. The whole cycle may be duration dependent if both of the half cycles exhibit duration dependence, or if either one is duration dependent. However, it is also possible for the whole cycle to be duration dependent even if both half cycles are duration independent.
18. For the pre-Nasdaq subsample of Dow Jones, the mean durations are 7.1 months for bull markets, 11.7 months for bear markets, 19.1 months for both the bear-to-bull and bull-to-bear cycles. For the post-Nasdaq subsample, the mean durations are 6.2 months for bull markets, 12.7 months for bear markets, 19 months for bear-to-bull cycles, and 19.2 months for bull-to-bear cycles.

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