E C O N O M I C S B U L L E T I N

The Taiwan stock market does follow a random walk

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Abstract

Applying the Lo and MacKinlay variance ratio test on the weekly returns from the Taiwan stock market from 1990 to mid 2006, I obtained results strongly indicative of the fact that not only does the Taiwan composite stock index move in a random walk fashion, returns for the individual stocks do so as we. Previous authors employing the same methodology obtained opposite results, namely, that the movements of the Taiwan stock composite index do not follow a random walk.

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1. Introduction

The early work of Fama and French (1965) suggested that stock price movements are not correlated to such a degree that one can truly profit from the insignificant auto-corrlelations. This idea was substantiated in their later survey of the extant literature (Fama and French, 1970). Since then, a number of authors[1] have nevertheless discovered significant autocorrelation in both the U.S. and non-U.S. stock returns[2]. These findings put to question the perception that stock returns follow a random walk, or that stocks offer a positive long-run return but that whether a stock will move up or down on any given day is fifty-fifty.

Amongst these papers, the one by Lo and MacKinlay (1988) not only refuted the random walk hypothesis for the U.S. weekly returns, but it also presented later researchers with a powerful variance ratio test for the investigation of the applicability of the random walk hypothesis as a description of stock price movements for non-U.S. markets. This test is predicated upon the fact that for price movements that follow random walks, the variance of the log-price relatives, log P_t - log P_{t-1}, sampled at regular intervals of length time t, is n times the variance of the log-price relatives sampled at intervals of length time t/n. Hence the variance of the monthly sampled log-price relatives with a sampling interval of length four weeks is four times that of the weekly sampled. The test statistic derived by Lo and MacKinlay to test if a series of price movements follows a random walk is robust to many forms of heteroscedasticity and nonnormality.

Later on, Chang and Ting (2000) applied the Lo and MacKinlay methodology on the weekly movements of the Taiwan composite value-weighted stock market index (Taiex). These authors concluded that these movements do not fit a random walk. The data they used ran from 1971 to 1996. Taking into account that the Taiwan investment environment has changed much in the two decades since the inception of the Taiex in 1971, it is quite possible that the same Lo and MacKinlay methodology applied on more current data may produce different results. The present study extended the Chang and Ting (2000) study by incorporating Taiex values beyond 1996.

In contrast to Chang and Ting, the results obtained here are in strong support of the fact that the weekly movements of the Taiex do indeed follow a random walk. The data used are from 1971 to 2006.

This paper is organized as follows: Section 2 summarizes the Lo and MacKinlay

[1] Fama and French (1988), Poterba and Summers (1988), as well as Lo and MacKinlay (1988).
[2] Urrutia (1995) reported significantly autocorrelated Latin American monthly returns. Chang and Ting (2000) suggested that the Taiwan Composite Stock Index does not follow a random walk.

methodology. Section 3 presents the empirical results, and section 4 concludes.

2. Methodology

Let X_t denote the log of the price of some stock at time t, and that $X_t = \mu + X_{t-1} + \varepsilon_t$, then the price variable is said to increment in a random walk fashion. Here μ stands for an arbitrary drift parameter, and ε_t is the random disturbance allowed to vary with time[3] and deviate from normality. This specification of X_t is far more lenient than the traditional random walk specification which restricts ε_t to being identically and independently distributed (i.i.d.).

If the movement of X_t does follow a random walk, then the variance of $X_t - X_{t-1}$ is 1/n times the variance of $X_t - X_{t-n}$. Furthermore, given a finite number of price movements represented by nq+1 consecutive X_t s, written as $X_0, X_1, X_2, ..., X_{nq}$ and taken to be a segment from an infinite series, the question of whether $X_t = \mu + X_{t-1} + \varepsilon_t$ holds true for the entire series can be addressed by estimating the ratio of the variance of $X_t - X_{t-n}$ to 1/n the variance of $X_t - X_{t-1}$ as follows (Lo and MacKinlay, 1988), under the random walk hypothesis, this variance ratio has a value close to one.

Let $\hat{\mu} = \frac{1}{nq}\sum_{k=1}^{nq}(X_k - X_{k-1}) = \frac{1}{nq}(X_{nq} - X_0)$, $\bar{\sigma}_a^2 = \frac{1}{nq-1}\sum_{k=1}^{nq}(X_k - X_{k-1} - \hat{\mu})^2$, and $\bar{\sigma}_c^2(q) = \frac{1}{q(nq-q+1)(1-\frac{q}{nq})}\sum_{k=q}^{nq}(X_k - X_{k-q} - q\hat{\mu})^2$, then $\bar{\sigma}_a^2$ and $\bar{\sigma}_c^2(q)$ are unbiased estimators for the variances of $X_t - X_{t-1}$ and $X_t - X_{t-q}$ respectively (Lo and MacKinlay, 1988). Now, let $VR(q) = \frac{\bar{\sigma}_c^2(q)}{\bar{\sigma}_a^2}$, q = 2, 4, 8, and 16, then under the random walk hypothesis, the four variance ratios $VR(2)$, $VR(4)$, $VR(8)$, and $VR(16)$ will all have values close to one since the variance of the increments of a random walk is linear in the sampling interval. To test whether the variance ratios of the sampled price movements deviate enough from unity to reject the random walk hypothesis, Lo and MacKinlay (1988) derived the asymptotically standard normal

[3] One example is when the variance varies in a deterministic fashion; another is when conditional variance varies with past information.

statistic $z(q) = \frac{\sqrt{nq}(VR(q)-1)}{\sqrt{\sum_{j=1}^{q-1}\left[\frac{2(q-j)}{q}\right]^2 \hat{\delta}(j)}}$, where

$\hat{\delta}(j) = \frac{nq\sum_{k=j+1}^{nq}(X_k - X_{k-1} - \hat{\mu})^2 (X_{k-j} - X_{k-j-1} - \hat{\mu})^2}{\left[\sum_{k=1}^{nq}(X_k - X_{k-1} - \hat{\mu})^2\right]^2}$. It has also been shown in Lo and MacKinlay (1988) that when q = 2, $VR(q)$ -1 estimates the first-order autocorrelation coefficient of the ($X_t - X_{t-1}$)s. Thus, if the X_t s are weekly prices, then $VR(2)$ approximates the first-order autocorrelation of weekly returns.

3. Data and results

The data are from the Taiwan Economic Journal data bank. These are the Friday values of the Taiex at the market's close. Under investigation is whether weekly movements of the Taiex follow a random walk. Results are presented in table 1.

Table 1

Variance ratios for the weekly values of the Taiex and the corresponding z statistics for the null hypothesis that a ratio has a value of 1

Sampling period: 1990.01.06 to 2006.11.03					
For	q = 2	nq = 864	VR(q) = 0.97	z(q) = -0.52	NOT rejected at 5%
	q = 4	nq = 864	VR(q) = 1.09	z(q) = 0.80	NOT rejected at 5%
	q = 8	nq = 864	VR(q) = 1.25	z(q) = 1.51	NOT rejected at 5%
	q = 16	nq = 864	VR(q) = 1.41	z(q) = 1.78	NOT rejected at 5%
Sampling period: 1990.01.06 to 2000.12.30					
For	q = 2	nq = 560	VR(q) = 0.97	z(q) = -0.35	NOT rejected at 5%
	q = 4	nq = 560	VR(q) = 1.12	z(q) = 0.84	NOT rejected at 5%
	q = 8	nq = 560	VR(q) = 1.30	z(q) = 1.42	NOT rejected at 5%
	q = 16	nq = 560	VR(q) = 1.46	z(q) = 1.56	NOT rejected at 5%
Sampling period: 2001.01.05 to 2006.11.03					
For	q = 2	nq = 288	VR(q) = 1.01	z(q) = 0.23	NOT rejected at 5%
	q = 4	nq = 288	VR(q) = 1.01	z(q) = 0.10	NOT rejected at 5%
	q = 8	nq = 288	VR(q) = 1.09	z(q) = 0.43	NOT rejected at 5%

q = 16	nq = 288	VR(q) = 1.27	z(q) = 0.91	NOT rejected at 5%

$VR(q) \equiv \frac{\overline{\sigma}_c^2(q)}{\overline{\sigma}_a^2}$, where $\overline{\sigma}_a^2$ is the estimated variance of the weekly differences $X_t - X_{t-1}$, and $\overline{\sigma}_c^2(q)$ is meant to provide an unbiased estimation of 1/q times the variance of $X_t - X_{t-q}$. Under the random walk null hypothesis, the variance ratio $VR(q)$ is 1, and the test statistic z(q) follows a standard normal distribution asymptotically. The last column tells whether the random walk hypothesis is rejected at the 5 percent level of significance. nq denotes the number of weekly observation in the series.

Table 1 presents the variance ratios based on the weekly values of the Taiex. Also shown are the corresponding z statistics for the null hypothesis that a ratio has a value of 1. Data from three sampling periods are used. The full sample period runs from Jan 6, 1990 through Nov 3, 2006 with a total of 864 weekly Taiex values. However, realizing that test results can be highly time-dependent, the full sample period is subdivided into two shorter sub-periods. For each period sampled in table 1, if the data support the random walk hypothesis, the VR(q)s have values close to 1 for the values of q assigned. This is in fact the case with the result presented in table 1. The random walk hypothesis, i.e. the hypothesis that the variance ratio is equal to 1, is not rejected by the data from the full sample period, nor by the data from the sub-periods. None of the test statistic z(q) is large or small enough to reject the hypothesis that the corresponding variance ratio is in fact 1. As mentioned before, the variance ratio VR(q) when q = 2 is approximately equal to 1 plus the first-order autocorrelation coefficient estimator of weekly returns. Thus, the first-order autocorrelation for the weekly returns in the full sample period is a mere -.03; and for the two sub-periods, -.03 and .01 respectively. Overall, the results obtained provide strong support that the increments of the Taiex follow a random walk.

As mentioned before, Chang and Ting (2000) applied the same methodology on the weekly movement of the Taiwan stock index and obtained drastically different results from those presented in this paper. These authors employed data from the 1970s and the 1980s in their study and obtained consistently strong rejection of the random walk hypothesis at the 5 percent level. However, the 1970s and the 1980s were the Taiwan market’s formative years and it is highly plausible that a fledgling market is less efficient that a matured one. That being said, it is highly suspected that Chang and Ting’s results are mainly caused by data from these two decades. Therefore, the Taiex values from the two decades are put through the test. The results are in table 2.

Table 2

Results for the weekly movements of the Taiex

Sampling period: 1971.01.09 to 1989.12.28

q = 2	nq = 976	VR(q) = 1.21	z(q) = 4.25	rejected at 5%
q = 4	nq = 976	VR(q) = 1.49	z(q) = 5.35	rejected at 5%
q = 8	nq = 976	VR(q) = 1.64	z(q) = 4.40	rejected at 5%
q = 16	nq = 976	VR(q) = 1.78	z(q) = 3.66	rejected at 5%

$VR(q) \equiv \frac{\overline{\sigma}_c^2(q)}{\overline{\sigma}_a^2}$, where $\overline{\sigma}_a^2$ is the estimated variance of the weekly differences $X_t - X_{t-1}$, and $\overline{\sigma}_c^2(q)$ is meant to provide an unbiased estimation of 1/q times the variance of $X_t - X_{t-q}$. Under the random walk null hypothesis, the variance ratio $VR(q)$ is 1, and the test statistic z(q) follows a standard normal distribution asymptotically. The last column tells whether the random walk hypothesis is rejected at the 5 percent level of significance. nq denotes the number of weekly observation in the series.

When the tests are performed solely on data from the formative years of the Taiwan stock market, the random walk hypothesis is soundly rejected as a description of how the Taiwan stock index behaves. The large VR(2) value of 1.21 says that the series from 1971 to 1989 is much highly autocorrelated than the one whose results are presented in table 1. To give an idea of how the Taiwan stock index has progressed since its inception in 1971 the following table is provided:

Table 3

Historical annual data of the Taiwan stock market

	Taiex (close)	Volume (Mil.Shares)	Amount (NTD$M)	Market Cap. (NTD$1000,000)
1971/12	135.13	626	11,791	19,006
1972/12	228.03	1,512	33,622	27,319
1973/12	495.45	2,216	77,290	76,358
1974/12	193.06	1,907	42,164	47,854
1975/12	330.08	4,998	115,022	70,407
1976/12	372.20	6,540	120,292	91,995
1977/12	450.44	9,285	153,409	117,756
1978/12	532.43	16,913	331,507	150,776
1979/12	549.55	11,030	201,176	176,796
1980/12	558.45	9,520	147,591	220,749
1981/12	551.03	13,065	209,040	214,998

1982/12	443.57	10,092	133,718	192,941
1983/12	761.92	23,834	364,473	294,503
1984/12	838.07	17,998	324,168	359,508
1985/12	835.12	14,384	192,850	401,988
1986/12	1039.11	38,907	675,158	538,987
1987/12	2339.86	76,763	2,658,300	1,351,798
1988/12	5119.11	105,316	7,915,103	2,871,755
1989/12	9624.18	238,553	25,678,970	5,783,654
1990/12	4530.16	315,611	21,362,541	2,902,835
1991/12	4600.67	217,531	10,313,905	3,150,270
1992/12	3377.06	133,359	6,272,636	2,546,082
1993/12	6070.56	227,267	9,285,984	4,960,449
1994/12	7124.66	407,565	19,436,364	6,444,619
1995/12	5173.73	282,319	10,292,327	5,122,473
1996/12	6933.94	375,676	13,138,220	7,322,298
1997/12	8187.27	691,680	37,710,886	9,792,209
1998/12	6418.43	621,975	29,760,177	8,246,752
1999/12	8448.84	689,497	29,490,923	11,734,777
2000/12	4739.09	647,961	30,816,356	8,162,575
2001/12	5551.24	617,632	18,410,427	10,203,381
2002/12	4452.45	890,131	21,937,159	8,919,056
2003/12	5890.69	1,036,666	20,482,274	12,401,992
2004/12	6139.69	1,099,255	24,177,828	13,880,077
2005/12	6548.34	791,722	19,050,955	15,566,232

Looking at table 3, it is easy to see that in terms of the value of the Taiwan composite index (Taiex), volume traded, amount traded, and market capitalization, the Taiwan market prior to the late 80's was but a miniature of what it has become today. The close scrutiny that a large market is subjected to may help explain why the Taiwan market is more random in the recent years.

4. Conclusions

Applying the Lo and MacKinlay variance ratio methodology onto the Taiex values from 1990 to 2006, it has been shown that the weekly movements of the Taiwan Composite Stock Index do seem to follow a random walk. However, the same test performed on the index values taken between 1971 and 1989 resulted in the strong rejection of the random walk. Looking at the historical data of the Taiwan market, it is plausible that the discrepancy in results can be due to the fledgling nature of the market at the earlier time period. In the 1970s and the 1980s, the Taiwan market was still at its infancy, trade values and volumes as well as total market capitalization were still very small; since then, the market has experienced tremendous growth. It is therefore reasonable to conjecture that the subsequent increase in the degree of scrutiny the market is subjected to as it matured has made the market more random in terms of price movements.

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