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

Structural Change in the Efficiency of the Japanese Stock Market after the Millennium

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Abstract

The Japanese stock market has important linkages with stock markets worldwide. This note examines whether the Japanese stock market is efficient in the past two decades. The profitability of various time-series model based trading rules is evaluated. It is found that most of these trading rules are not profitable, suggesting that the Japanese stock market is efficient since the mid 1980¡¦s. The efficiency has been slightly improved after the millennium.

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1. Introduction

Technical trading rules have long been adopted by market participants for hundreds of years since the invention of the Japanese candlestick in the 17th century. There have been a good number of empirical studies on the profitability of various technical trading rules in the literature. For example, Fama (1966), Jensen and Benington (1970) and Neftci (1991) show that historical prices cannot be used to predict the future movements of stock prices. Hudson *et al*. (1996) and Mills (1997) also find that technical analysis does not perform well in the U.K. stock market. However, Brock *et al*. (1992) show that the moving average (MA) and the trading range break (TRB) rules manage to generate abnormal profits on the Dow Jones Industrial Average Index. Other studies such as Coutts and Cheung (2000) and Taylor (2000) also conclude that abnormal profits exist for simple trading rules. Andrada-Félix *et al*. (2003) show that the nearest-neighbour (NN) rule is better than the buy-and-hold (B-H) rule in the NYSE index. Pérez-Rodríguez *et al*. (2005) evaluate the effectiveness of the artificial neural network (ANN) and the smooth transition autoregressive (STAR) models in the Spanish market. It is found that the ANN and the STAR forecasts can generate abnormal profits.

This note examines if simple time-series based trading rules are profitable in the Japanese stock market. The Japanese market is studied because of its important linkages with stock markets worldwide. In this paper, we examine the simple AR(1) trading rule and the rules that based on moving averages. Let Y_t be the log price of the stock index at time t, the following AR(1) model is estimated:

$$\Delta Y_t = \lambda_0 + \lambda_1 \Delta Y_{t-1} + \varepsilon_t \,. \tag{1}$$

The trading rule is as follows:

$$\text{Buy if } E^w_t(\Delta Y_{t+1}) > 0 \,, \tag{2}$$

$$\text{Sell if } E^w_t(\Delta Y_{t+1}) < 0 \,. \tag{3}$$

ΔY_{t+1} is the daily period return at *t + 1*, *w* stands for the length of the observation window and E^w_t refers to the expectation conditional on the previous *w* observations up to day *t*. A moving average of window size w is defined as:

$$MA_t(w) = \frac{\sum_{t=1}^{w} P_t}{w} \,. \tag{4}$$

The strategies adopted are the variable length moving average (VMA) rules of Brock *et al*. (1992). The VMA(S,L) trading rule is defined as follows:

$$\text{Buy if } MA_t(S) > MA_t(L) \,, \tag{5}$$

$$\text{Sell if } MA_t(S) < MA_t(L) \,, \tag{6}$$

where $MA_t(S)$ and $MA_t(L)$ represent the short-term MA and the long-term MA respectively, where $S < L$. The VMA rules under study are VMA(1,50), VMA(1,150), VMA(1,200), VMA(5,150) and VMA(2,200).

2. Data and Methodology

5723 daily observations of the NIKKEI 225 index from January 1985 to December 2006 are obtained from DataStream. To test whether there is a structural change in the trading rule profits after the millennium, we split the whole sample into two subsamples using the year 2000 as the cut-off year. The millennium is a natural choice for a number of reasons. First, it is just two years after the Asian Financial Crisis. Second, it is the year when the burst of the dotcom bubble occurs. Moreover, there have been worries that the millennium bug may affect the proper functioning of computers. Therefore, one would expect the market condition to be different after the millennium. Table 1 provides the summary statistics for the whole sample and subsamples.

Table 1: Summary statistics for the time series for the whole sample

Return of	Whole sample	Pre-2000	Post-2000
Observations	5722	3910	1812
Mean	0.000064	0.000126	-0.000071
Maximum	0.124303	0.124303	0.072217
Minimum	-0.161354	-0.161354	-0.072340
Std. Dev.	0.013467	0.013360	0.013698
Skewness	-0.144844	-0.146965	-0.139106
Kurtosis	10.6460	13.5890	4.8799
Jarque-Bera	13958	18282	273
Probability	0	0	0
Sum	0.364293	0.493594	-0.129301
Sum Sq. Dev.	1.037604	0.697756	0.339799
Ljung-Box Q-Statistic(5)	19.463**	25.3911**	4.3748
ρ(1)	-0.014583		
ρ(2)	-0.054723		
ρ(3)	0.003921		
ρ(4)	0.011977		
ρ(5)	-0.005742		

Note: Results are presented for sample before and after Jan 1, 2000. Returns are calculated as log difference of the stock index level. "JB stat" represents the Jarque-Bera test for normality. As for the Ljung-Box Q-statistic (5), (**) indicates that the numbers are significant at the 1% level.

The autocorrelations of the return series for the whole sample are also reported in Table 1. Note that there is a significant negative second order autocorrelation in the return series of NIKKEI 225. The Ljung-Box Q statistics in Table 1 show that the correlations within five lags are statistically significant at the 1% level before the millennium, but they are insignificant after the millennium.

We define the daily mean buy (sell) return ($\pi_{b(s)}$) as follows:

$$\pi_{b(s)} = \frac{1}{N_{b(s)}} \sum_{t=1}^{N} \Delta Y_{t+1} I_t^{b(s)} . \tag{7}$$

The sample variance ($\sigma^2_{b(s)}$) of the above return is:

$$\sigma^2_{b(s)} = \frac{1}{N_{b(s)}} \sum_{t=1}^{N} (\Delta Y_{t+1} - \pi_{b(s)})^2 I_t^{b(s)} \tag{8}$$

where $N_{b(s)}$ stands for the number of buy (sell) days, N is the number of observations for the complete sample, ΔY_{t+1} is the daily return, and $I_t^{b(s)}$ is an indicator function that equals one if a buy (sell) signal is generated at time t and equals zero otherwise. Following Brock *et al*. (1992), we test the difference of the mean buy return and the mean sell return from the unconditional mean. We also test the significance of buy-sell return from zero. The null and alternative hypotheses and the conventional t-statistic for the mean buy (sell) return are respectively given by:

$$H_0 : \quad \pi_{b(s)} = \overline{\pi}$$
$$H_1 : \quad \pi_{b(s)} \neq \overline{\pi}$$

$$t_{b(s)} = \frac{\pi_{b(s)} - \overline{\pi}}{\left(\frac{\sigma^2}{N_{b(s)}} + \frac{\sigma^2}{N} \right)^{1/2}} , \tag{9}$$

where $\overline{\pi}$ is the unconditional mean and σ^2 is the unconditional variance. For the buy-sell return, the null and alternative hypotheses are as follows:

$$H_0 : \quad \pi_b - \pi_s = 0$$
$$H_1 : \quad \pi_b - \pi_s \neq 0$$
$$t_{(b-s)} = \frac{\pi_b - \pi_s}{\left(\frac{\sigma^2}{N_b} + \frac{\sigma^2}{N_s} \right)^{1/2}} . \tag{10}$$

To allow for the possibility of a change in the market state after the millennium, the corresponding mean return is subtracted from the buy-sell return before making the comparison. In other words, we test

$$H_0 : (\pi_{b1} - \pi_{s1}) - \overline{\pi}_1 = (\pi_{b2} - \pi_{s2}) - \overline{\pi}_2$$
$$H_1 : (\pi_{b1} - \pi_{s1}) - \overline{\pi}_1 \neq (\pi_{b2} - \pi_{s2}) - \overline{\pi}_2$$

The test statistic is as follows:

$$t = \frac{((\pi_{b1} - \pi_{s1}) - \overline{\pi_1}) - ((\pi_{b2} - \pi_{s2}) - \overline{\pi_2})}{\sigma\sqrt{\frac{1}{N_{b1}} + \frac{1}{N_{s1}} + \frac{1}{N_1} + \frac{1}{N_{b2}} + \frac{1}{N_{s2}} + \frac{1}{N_2}}}, \qquad (11)$$

where $\pi_{b(s)i}$ stands for mean buy (sell) return in period i (i = 1, 2), and $\overline{\pi_i}$ stands for the mean return in period i (i = 1, 2). N_{bi} and N_{si} are the number of buys and sells of the i^{th} subsample respectively, and N_i is the total number of observations of the i^{th} subsample. σ is the sample standard deviation of the whole sample[2].

3. Results and Conclusions

Table 2 shows the empirical results of the trading strategies applying to the whole sample. AR(1,w) stands for the AR(1) rule using w observations.

Table 2: Empirical result for the NIKKEI 225 Index, Japan

Trading Rule	N(Buy)	N(Sell)	σ(Buy)	σ(Sell)	Mean Return	σ	Buy	Sell	Buy-Sell
AR(1,50)	3073	2599	0.01147	0.01560	0.000051	0.01352	0.000022	0.000085	-0.000062
							(-0.09402)	(0.10513)	(-0.17247)
AR(1,150)	3041	2531	0.01103	0.01615	0.000051	0.01360	0.000283	-0.000227	0.000510
							(0.75512)	(-0.85336)	(1.39299)
AR(1,200)	3049	2473	0.01143	0.01597	0.000045	0.01366	0.000299	-0.000267	0.000565
							(0.82176)	(-0.94475)	(1.52985)
VMA(1,50)	3063	2610	0.01114	0.01586	0.000052	0.01352	0.000297	-0.000236	0.000532
							(0.80781)	(-0.89872)	(1.47790)
VMA(1,150)	2993	2580	0.01073	0.01630	0.000051	0.01360	0.000362	-0.000311	0.000673
							(1.01081)	(-1.11600)	(1.84182)
VMA(1,200)	2970	2553	0.01064	0.01648	0.000047	0.01366	0.000312	-0.000262	0.000574
							(0.85371)	(-0.94427)	(1.55710)
VMA(5,150)	2991	2582	0.01091	0.01614	0.000051	0.01360	0.000631	-0.000622	0.001253
							(1.88281)	(-2.07665*)	(3.42899**)
VMA(2,200)	2965	2558	0.01076	0.01638	0.000047	0.01366	0.000353	-0.000309	0.000662
							(0.98597)	(-1.08791)	(1.79603)

(*) indicates that the numbers are significant at the 5% level.
(**) indicates that the numbers are significant at the 1% level.

From Table 2, only the VMA(5,150) rule produce significant buy-sell returns. In general, the time-series based trading strategies are not profitable in the Japanese stock market. Tables 3a and 3b report the performances of the trading strategies on the two subsamples.

[2] For a detailed analysis for this kind of comparison, one is referred to Hawkins (1977) and Chong (2001).

Table 3a: Result of the first subsample (Jan 1985 to Dec 1999)

Trading Rule	N(Buy)	N(Sell)	σ(Buy)	σ(Sell)	Mean Return	σ	Buy	Sell	Buy-Sell
AR(1,50)	2163	1697	0.01103	0.01598	0.000108	0.01343	0.000199	-0.000008	0.000207
							(0.25243)	(-0.29670)	(0.47556)
AR(1,150)	2121	1639	0.01052	0.01668	0.000110	0.01356	0.000482	-0.000371	0.000853
							(1.00971)	(-1.19880)	(1.91264)
AR(1,200)	2084	1626	0.01092	0.01647	0.000102	0.01364	0.000395	-0.000272	0.000667
							(0.78267)	(-0.92331)	(1.47742)
VMA(1,50)	2136	1725	0.01078	0.01611	0.000110	0.01343	0.000395	-0.000244	0.000638
							(0.78736)	(-0.90782)	(1.46807)
VMA(1,150)	2136	1625	0.01016	0.01702	0.000110	0.01356	0.000354	-0.000212	0.000566
							(0.66538)	(-0.79822)	(1.26752)
VMA(1,200)	2083	1628	0.01002	0.01718	0.000104	0.01364	0.000373	-0.000239	0.000612
							(0.71944)	(-0.84777)	(1.35727)
VMA(5,150)	2132	1629	0.01038	0.01680	0.000110	0.01356	0.000619	-0.000556	0.001175
							(1.38502)	(-1.65677)	(2.63429*)
VMA(2,200)	2081	1630	0.01018	0.01705	0.000104	0.01364	0.000401	-0.000274	0.000675
							(0.79366)	(-0.93385)	(1.49607)

Table 3b: Results for the subsample (Jan 2000 to Dec 2006)

Trading Rule	N(Buy)	N(Sell)	σ(Buy)	σ(Sell)	Mean Return	σ	Buy	Sell	Buy-Sell
AR(1,50)	863	899	0.01249	0.01488	-0.000097	0.01376	-0.000455	0.000246	-0.000701
							(-0.62527)	(0.60846)	(-1.06844)
AR(1,150)	832	830	0.01188	0.01524	0.000030	0.01367	-0.000090	0.000149	-0.000239
							(-0.20577)	(0.20610)	(-0.35669)
AR(1,200)	860	752	0.01212	0.01530	0.000024	0.01370	0.000254	-0.000238	0.000492
							(0.39638)	(-0.43346)	(0.71866)
VMA(1,50)	881	882	0.01200	0.01532	-0.000095	0.01376	0.000073	-0.000262	0.000336
							(0.29571)	(-0.29549)	(0.51200)
VMA(1,150)	777	886	0.01180	0.01511	0.000017	0.01367	0.000470	-0.000381	0.000850
							(0.76261)	(-0.69873)	(1.26555)
VMA(1,200)	807	806	0.01172	0.01542	0.000020	0.01370	0.000231	-0.000190	0.000421
							(0.35651)	(-0.35681)	(0.61776)
VMA(5,150)	780	883	0.01193	0.01502	0.000017	0.01367	0.000728	-0.000612	0.001340
							(1.19888)	(-1.10376)	(1.99414*)
VMA(2,200)	803	810	0.01175	0.01538	0.000020	0.01370	0.000296	-0.000253	0.000549
							(0.46587)	(-0.46318)	(0.80458)

Again, only the VMA(5,150) rule is able to produce significant buy-sell returns. Note from Tables 3a and 3b that the t-statistics for the buy-sell return are slightly reduced after the millennium. In addition, the buy-sell returns are all positive for the first subsample, while the first two AR rules generate negative buy-sell returns for the second subsample. Thus, the trading rules are less profitable after the millennium. To test the significance of this reduction in profitability, Table 4 reports the testing results for the difference of the buy-sell return before and after the millennium using Equation (11). From the results of Table 4, we see that there is a marginal reduction in the profitability of the AR(1,150) rule after the millennium.

Table 4: Testing for structural change in the buy-sell return before and after year 2000

Trading Rule	t-statistic
AR(1,50)	0.8067
AR(1,150)	1.1269
AR(1,200)	0.1063
VMA(1,50)	0.1132
VMA(1,150)	-0.4203
VMA(1,200)	0.1172
VMA(5,150)	-0.2865
VMA(2,200)	0.0460

Note: The t-statistics are calculated using Equation (11).

In a nutshell, this note shows that the time-series based trading rules under study are not profitable. For the AR rules, most of the t-statistics are positive but insignificant. For the MA strategies, all the t-ratios are insignificant. Thus, it is difficult for the time-series based trading rules to beat the Japanese stock market. The structural-change test suggests that our results are robust to the choice of sample period. Our findings provide supporting evidence that the world's second largest stock market is highly developed and efficient over the past two decades. Last but not least, it should be mentioned that the values of the t test and Q test are generally lower in the second subsample, implying that the market efficiency of Japan has been slightly improved after the millennium.

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