Weak-Form Market Efficiency: Evidence from the Brazilian Stock Market

Chien-Ping Chen[1] & Massoud Metghalchi[1]

[1] School of Business Administration, University of Houston-Victoria, Victoria, Texas, USA

Correspondence: Chien-Ping Chen, 14000 University Blvd, Sugar Land, TX 77479, USA. Tel: 1-281-275-8811. E-mail: chenc@uhv.edu

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Abstract

We investigate the predictive power of various trading rules with different combinations of the most popular indicators in technical analysis for the Brazilian stock index (BOVESPA) over the period of 5/1/1996 to 3/1/2011, or 14.83 years. The empirical results show that all the buy-sell differences under single, double and triple-indicator combinations are insignificant in t-test; that is, technical trading models cannot beat the buy and hold strategy. Although few multiple-indicator trading models show profitability, their predictive power is eliminated after considering the possible interest earning from money market in the days out of stock market. The results support strongly the weak form of market efficiency for the Brazilian stock market.

Keywords: emerging markets, hypothesis testing, market efficiency, profitability

1. Introduction

Since Fama (1970) defined the Efficient Market Hypotheses (EMH) asserting that stock prices already reflect all available information, numerous empirical studies have been trying to confirm or oppose it in a stock market. There are three forms or levels of EMH:

Strong efficiency - All information in a market, whether public or private, is accounted into a stock price. No investor can earn excess return.

Semi-strong efficiency - All public information in a market is accounted into a stock price. Neither fundamental nor technical analysis can beat a market to achieve superior gains.

Weak efficiency - All past stock prices are reflected in today's price. Fundamental analysis can be used to identify stocks that are undervalued and overvalued and investors can choose a profitable company by researching its financial statements. However, technical analysis cannot be used to predict and beat a market.

Contrast to fundamental analysis focusing on income statement or balance sheet of a company, technical analysis is based upon the assumption that past price, past volume and many other indicators calculated by past data can signal future price movements. As Pring (1991) noted, "The art of technical analysis is to identify trend changes at an early stage and to maintain an investment posture until the weight of evidence indicates that the trend has reversed." Murphy (1999) also defined technical analysis as the study of market action through the use of charts for the purpose of forecasting future prices, in which a market action can be price, volume, or open interest. As a result, in order to prove the predictive power of technical analysis, stock technicians test the Weak-Form Efficient Market Hypotheses (WFEMH) by the following two approaches: (1) using the past return series or price information to determine the existence of predictability by random walk testing, or (2) applying various trading rules to seek any profit-making strategy which can drive profits above a general buy-and-hold strategy; in other words, whether trading rules can beat the market or not.

Since the Millennium, stock markets in the fast growing emerging economies have attracted the attention of the researchers and investors across the globe. With the increased movement of investments into emerging markets, greater importance is also given to the understanding of the market efficiency in emerging markets. Among the emerging countries, Brazil, Russia, India and China (BRIC) are recognized as the most influential in the new world economy to raise more interests in testing the WFEMH. Not surprisingly, in a transition period from emerged to developed, BRIC stock markets are considered to be immature due to the altering legislation environment and market structure. Investors are expected to achieve superior gains from private information or profitable trading rules. Most recently empirical works applying either random walk testing or trading rule approach, also confirm the market inefficiency in the BRIC countries except for Brazil. The Brazilian stock index (BOVESPA) has shown relatively ambiguous testing results of the WFEMH compared with those in Russia, India and China. Some comparative studies conclude that the Brazilian stock market is more efficient than the others but cannot confirm its weak form market efficiency. Some studies only confirm the WFEMH for a certain sector or size of firms. Whether trading rules can beat the Brazilian stock market to reject the WFEMH is still questionable.

In order to obtain a more convinced result for market efficiency, we employ various trading rules with different combinations of the most popular indicators in technical analysis to test the WFEMH in the Brazilian stock index (BOVESPA) over the period of 1996 to 2011. The empirical results show that all the buy-sell differences, under our 32 trading rules of single, double or triple-indicator combinations, are insignificant in t-test. That is, none of the trading model can beat the buy-and-hold strategy for superior gains. The results support strongly the WFEMH for the Brazilian stock market in a long period. Section 2 discusses a brief literature review. The data and methodology are shown in Section 3. Section 4 presents our findings and the final section concludes.

2. Literature Review

Early literatures of efficient market hypothesis (EMH) supported the futility of technical analysis in many financial markets around the world. However, since the mid 1980s, there have been numerous empirical studies supporting the predictability and profitability of technical trading rules in stock markets. The origin of this new found interest was from a few influential academic articles by Sweeney (1986), Lukac, Brorsen & Irwin (1988), and Brock, Lakonishok & Lebaron (1992). After these three studies, many academicians have pursued their works and published a myriad of papers in opposition to the efficient market hypothesis by constructing technical trading rules to beat the market rather than using the random walk testing. Applying the moving average trading rule in Brock et al. (1992), numerous studies such as Hudson, Dempsey & Keasey (1996), Rodríguez, Sosvilla & Andrada (1999) and Kwan, Lam, So & Yu (2000) proved the predictive power of technical analysis in the UK stock market, Madrid Stock Exchange and the Hang Seng Index Futures respectively. Since the twenty-first century, there were even more studies applying a variety of indicators to prove the profitability of technical analysis in stock markets around the world. For example, Kwon and Kish (2002) confirmed that technical trading rules can add a value to capture profit opportunities over a buy and hold strategy for the NYSE value-weighted index. Metaghachi and Chang (2003) and Chang, Metghalchi & Chan (2006) applied various moving average rules to conclude the profitability of technical trading in the Italian and the Taiwanese stock markets. Wong, Manzur & Chew (2003) investigated the Singapore data to indicate that the moving average and the relative strength index (RSI) can be used to generate significantly positive return. Vasiliou, Eriotis & Papathanasiou (2006) supported the profitability of moving average convergence divergence (MACD) in the Athens Stock Market. Lento (2007) examined the effectiveness of nine technical trading rules, including filter rules (momentum strategies) in many Asian-Pacific stock markets and concluded that technical trading rules are more profitable in most of the markets except the Nikkei index. Metghalchi, Chang & Marcucci (2008), Metghalchi, Du & Ning (2009), Metghalchi and Garza-Gomez (2011), and Chen, Metghalchi & Garza-Gomez (2011) presented that the technical trading rules including directional movement system (DMS) and parabolic stop and reverse (PSAR), can beat the buy and hold strategy in the Swedish market, four Asian stock markets, the Abu Dhabi stock index, and the Danish stock market respectively. The Weak-Form Efficient Market Hypotheses (WFEMH) has been rejected successfully by the profitability of trading rules with a variety of indicators in several relatively developed counties.

For the emerging economies such as the BRIC countries, most previous studies in the market efficiency use the past return series or price information to determine the existence of predictability by random walk testing. McGowan and Ibrihim (2009) investigated the Russian stock index in the period of 1995 to 2003 and confirmed the day-of-the-week effect to reject its weak-form market efficiency. Chong, Cheng & Wong (2010) also found that the Russian market is the most insufficient of market efficiency among BRICs. For India, Poshakwale (1996) provided evidence of the day-of-the week effect in Bombay Stock Exchange over a period of 1987-1994. Both Gupta and Yang (2011) and Kumar and Kumar (2012) applied random walk test for the period of 1997 to 2011 in the major equity markets BSE and NSE in India to reject the weak-form efficiency for daily data. Mitra and Mitra (2011) analyzed the profitability of moving average based trading rules and concluded that profit opportunities from technical analysis continue to remain an interesting and debatable issue in the Indian stock market. For China, Lim, Habibullah & Hinich (2009) mitigated the confounding effect of thin trading on return autocorrelation to examine both the Shanghai and Shenzhen Stock Exchanges. The weak-form market efficiency is rejected in certain time periods. Liu (2011) employed unit root test and autocorrelation function to examine the period over 2000 to 2008. Again, the weak-form efficiency in the Chinese stock market is rejected.

Interestingly, the empirical studies for the Brazilian stock market presented relatively ambiguous results for market efficiency. Guttler (2008) employed both co-integration analysis and a variety of Granger causality tests to reject the semi-strong market efficiency for the Brazilian stock index (BOVESPA) in the period from 1995 to 2005. It was found to be inefficient in line with most results for other emerging markets. Chong et al. (2010) compared the stock market efficiency of all the BRICs over the period of 1995 to 2008 to test the profitability of trading rules. It found that the Brazilian market is the most efficient among the BRICs but the WFEMH is still not supported. Ely (2011) grouped stocks by sector and firm size with data from 1999 to 2008 in the Brazilian stock market to examine the market efficiency by conducting an automatic variance ratio test. Stocks from the industrial sector are found highly predictable and stocks from small firms tend to be more predictable than the ones from large firms. The Brazilian stock market shows an increase of efficiency since 1994. However, there is still lack of strong evidence to support or reject the weak-form market efficiency for the Brazilian stock market.

3. Data and Methodology

We obtained the daily price data from the DataStream, including close, high, low and open, for the Brazilian stock index (BOVESPA) from 5/1/1996 to 3/1/2011, or 14.83 years. The period is the longest among all recent studies related to the Brazilian stock market efficiency. For the interest rate adjustment, we also used the DataStream's Brazilian overnight rate. A number of technical trading rules with two or three popular indicators in technical analysis are applied into the BOVESPA. When a trading rule emits a buy signal, then we will be in the market (buy days); otherwise we will be out of the market (sell days).

3.1 Technical Analysis Indicators

Similar to Chen et al. (2011), the following six popular indicators are used in our trading rules: Moving Average (MA), Relative Strength Index (RSI), Directional Movement System (DMS), Parabolic Stop and Reverse (PSAR), Moving Average Convergence Divergence (MACD) and Stochastic indicator.

1) Moving Average (MA): Only MA20 and MA50 are chosen. A buy signal is emitted when the price is above MA and a sell signal is emitted when the index goes below MA.

2) Relative Strength Index (RSI): The RSI indicator was developed by Wells Wilder (1978). It is generally constructed by using 14 day, 9 day or 3 day period. The calculation of *n*-day RSI (*RSI-n*) is described as the following:

AU_n = Average of *n* days' up closes

AD_n = Average of *n* days' down closes

$$RSI - n = \frac{AU_n}{AU_n + AD_n} \times 100$$

Given the definition, every RSI ranges from 0 to 100. In our trading rules, a buy signal is emitted if RSI is above 50 (buy day). Otherwise, we will be out of the market and it will be a sell day.

3) Directional Movement System (DMS): The DMS is another widely used indicator developed by Wells Wilder (1978). It consists of two directional daily movements, positive directional index (PDI) and negative directional index (NDI), signifying the up and down movements respectively. The signals are constructed in the following:

Positive directional movement (PDM) = $H - H_P$

Negative directional movement (NDM) = $L_P - L$

H = the highest price today

H_P = the highest price yesterday

L_P = the lowest price yesterday

L = the lowest daily price today

If PDM < 0 and NDM < 0 or PDM = NDM, then PDM = 0 and NDM = 0.

If PDM > NDM, then NDM = 0.

If NDM > PDM, then PDM = 0.

We also define the True Range (TR) as the maximum difference of the following:

TR = Max ($|H-L|$, $|H-C_P|$, $|C_P - L|$), where C_P is the closing price of previous day.

Similar to Wilder (1978), we also employ the exponential smoothing technique of 14-day to smooth PDM, NDM and TR. Finally, the positive directional index (PDI) and negative directional index are:

PDI = Smoothed PDM/Smoothed TR= SPDM/STR

NDI = Smoothed NDM/Smoothed TR= SNDM/STR

We will be in the market if PDI is greater than NDI (buy day); otherwise, we will be out of the market (sell day).

4) Parabolic Stop and Reverse (PSAR): It is the third indicator used in Wilder (1978). The value of PSAR serves as a benchmark for the up and down trend. In a bull (bear) market, it is below (above) the market price. The daily PSAR values are calculated as

$$SAR_{i+1} = SAR_i + AF*(EP_i - SAR_i),$$

where SAR_i is the PSAR value in the previous day and EP_i (Extreme Price) is the highest or the lowest price in the previous day. AF is the acceleration factor increasing by 0.02 whenever the EP is changing. Recommended in Wilder (1978), AF is capped at 0.20 for a better adjustment. When the index is above the PSAR value, we will be in the market (buy day) otherwise we will be out of the market (sell day).

5) Moving Average Convergence Divergence (MACD): This technical indicator, created by Appel (1974), shows the difference between exponential moving average (EMA) of 26 and 12 days. Then we construct a simple 9-day moving average of the MACD as the signal line and develop the histogram as follow:

$$MACD = EMA(CLOSE, 12) - EMA(CLOSE, 26)$$

Signal Line = Simple 9-day moving average of MACD

Histogram = MACD – Signal Line

Three trading rules are tested as follow: (i) a buy signal is emitted when the histogram is positive and we will be in the market (buy day) otherwise we will be out of the market as soon as the histogram becomes negative (sell day); (ii) a buy signal is emitted when the histogram is increasing and we will be in the market (buy day) otherwise we will be out of the market (sell day); and (iii) a buy signal is emitted when the histogram is increasing and greater than zero and we will be in the market (buy day) otherwise we will be out of the market (sell day).

6) Stochastic: The last popular indicator used in this paper is the stochastic indicator developed by Dr. George Lane in late 1950s, the Stochastic Oscillator. Two lines, the *%K* line and *%D* line, are constructed as the following to determine the signals:

$$\%K(today) = 100 \times \frac{close(today) - lowest\,low\,of\;\; past\,N\,days}{(high - low)\,range\,of\;\; past\,N\,days}$$

%D = 3-day exponential moving average of *%K*

In practice, 5, 9 and 14-day periods are commonly used by technicians. In order to be consistent with our previous works, we use the 9-day stochastic in this paper for more significant results. Another line, the *%D*-slow line constructed by 3-day simple moving average of *%D*, separates the stochastic indicators into fast and slow for more trading models:

Fast stochastic (*%K* and *%D* lines)

Slow stochastic (*%K* and *%D*-slow lines)

A buy signal is emitted (for both fast and slow stochastic indicators) if *%K* is above *% D* and if *% K* is increasing (buy day); otherwise we will be out of the market (sell day).

3.2 Models for Testing

In this paper, we test 32 models based on different combinations of the six indicators. They are categorized in the following three groups with single, double and triple indicators:

3.2.1 Single-Indicator Models (1~13)

Model 1: MA20. The model emits buy when the price goes above MA20 (buy day) and emits sell signal when the index goes below MA20 (sell day).

Model 2: MA50. The model emits buy when the price goes above MA50 (buy day) and emits sell signal when the index goes below MA50 (sell day).

Model 3: PSAR. If the stock index level is above PSAR, then it is a buy day; otherwise, it is a sell day.

Model 4: RSI-14. If it is above 50 then it is a buy day; otherwise, it is a sell day.

Model 5: RSI-9. If it is above 50 then it is a buy day; otherwise, it is a sell day.

Model 6: RSI-3. If it is above 50 then it is a buy day; otherwise, it is a sell day.

Model 7: Fast Stochastic. If *%K* line is above *%D* line, then it is a buy day; otherwise, it is a sell day.

Model 8: Increasing Fast Stochastic. If *%K* line is increasing and above *%D* line, then it is a buy day; otherwise, it is a sell day.

Model 9: Increasing Slow Stochastic. If *%K* line is increasing and above the *%D* slow-line, then it is a buy day; otherwise, it is a sell day.

Model 10: DMS. If the value of positive DI is greater than that of negative DI, then it is a buy day; otherwise, it is a sell day.

Model 11: MACD. If histogram is greater than zero, then it is a buy day; otherwise, it is a sell day.

Model 12: MACD. If histogram is increasing, then it is a buy day; otherwise, it is a sell day.

Model 13: MACD. If histogram is increasing and greater than zero, then it is a buy day; otherwise, it is a sell day.

3.2.2 Double-Indicator Models (14~24)

Given the 13 single-indicator models, we are supposed to develop more than 100 combinations of double-indicator models. However, in order to explore the significant results efficiently, we focus on the single-indictor models which demonstrate a relatively significant difference between the mean returns of buy days and sell days shown in Table 1. As a result, we pick the moving average, RSI-9 and 14, increasing fast stochastic and DMS, to construct the combinations of double and triple-indicator models.

Model 14: Combination of Model 1 (MA20) and Model 7 (Fast Stochastic). If stock index is above MA20 and *%K* is above *%D*, then we are in the market (buy day); otherwise, it will be a sell day.

Model 15: Combination of Model 1 (MA20) and Model 10 (DMS).

Model 16: Combination of Model 1 (MA20) and Model 4 (RSI 14).

Model 17: Combination of Model 1 (MA20) and Model 13 (MCAD).

Model 18: Combination of Model 2 (MA50) and Model 8 (Increasing Fast Stochastic)

Model 19: Combination of Model 2 (MA50) and Model 10 (DMS).

Model 20: Combination of Model 2 (MA 50) and Model 4 (RSI-14).

Model 21: Combination of Model 2 (MA 50) and Model 13 (MCAD).

Model 22: Combination of Model 8 (Increasing Fast Stochastic) and Model 10 (DMS).

Model 23: Combination of Model 5 (RSI-9) and Model 10 (DMS).

Model 24: Combination of Model 8 (Increasing Fast Stochastic) and Model 12 (MCAD)

3.2.3 Triple-Indicator Models (25~32)

Model 25: Combination of Models 1, 8 and 10; a buy signal is emitted when price is above MA 20, and *%K* is increasing and above *%D*, and PDI is above NDI. Otherwise, we will be out of the market (sell day).

Model 26: Combination of Models 2, 8 and 10.

Model 27: Combination of Models 1, 8 and 12.

Model 28: Combination of Models 1, 8 and 4.

Model 29: Combination of Models 2, 8 and 5.

Model 30: Combination of Models 10, 8 and 4.

Model 31: Combination of Models 10, 8 and 5.

Model 32: Combination of Models 1, 8 and 5.

3.3 Hypothesis Testing

For each model, the mean buy and mean sell returns are defined as follows:

$$X(b) = \frac{1}{N(b)} \sum R_b \tag{1}$$

$$X(s) = \frac{1}{N(s)} \sum R_s \tag{2}$$

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$N_{(b)}$ and $N_{(s)}$ are total number of buy and sell days; R_b and R_s are daily returns of buy and sell days for each model. We then test whether the mean returns of buy days and sell days are different than the mean return of buy-and-hold (B&H) strategy (h). In addition, we also test whether the mean buy is different than the mean sell. The three null and alternative hypotheses are expressed as:

$H_{0b}: X(b) - X(h)=0$ $H_{0s}: X(s) - X(h)=0$ $H_0: X(b) - X(s)=0$

$H_{Ab}: X(b) - X(h) \neq 0$ $H_{As}: X(s) - X(h) \neq 0$ $H_A: X(b) - X(s) \neq 0$

$X(h)$ is the mean return for the buy-and-hold strategy. Following Kwon and Kish (2002), the test statistic for the mean buy returns over the mean buy-and-hold strategy is:

$$t = \frac{X(b) - X(h)}{\sqrt{Var(b)/N_b + Var(h)/N_h}}, \tag{3}$$

where $Var(b)$ and $Var(h)$ are the variances of buy, and B&H returns respectively. By replacing the appropriate variables, the above formula can be also used to test the mean sell returns over the mean B&H strategy, and the mean buy returns over the mean sell returns.

4. Empirical Findings

The summary statistics for the B&H strategy for the entire period is as follow: the mean daily return of the B&H is 0.00061 (0.061 percent per day) for an annual arithmetic average of 15.64 % (Sum of daily returns divided by 14.83). The daily standard deviation of return for the B&H strategy is 0.02196 and the number of observation are 3818 days.

Table 1 presents the results of our first 13 single-indicator models. The results are surprisingly weak compared with those for the other countries. No single model has a t-test statistic greater than 1.96 or less than –1.96, the critical t-values at 5 percent level for large number of observations for a two-tailed test. That is, none of single-indicator trading rules can beat the market buy and hold strategy. Column 2 displays the difference of mean returns between buy days and B&H; Column 3 displays the difference of mean returns between sell days and B&H; Column 4 reports the difference of mean returns between buy days and sell days; Columns 5 and 6 report the standard deviations of returns on buy and sell days. Finally, Columns 7 and 8 show the total number of buy and sell days; the numbers in the parentheses are the t-statistics (i.e. Equation (3)) testing the difference of the mean buy and mean sell from the mean of B&H, and buy-sell from zero.

Table 1. Single-indicator models

Models	*X(b) –X(h)*	*X(s) –X(h)*	*X(b) –X(s)*	*SD(b)*	*SD(s)*	*N(b)*	*N(s)*
1	0.00120 (1.18)	–0.00031 (–1.16)	0.00151 (1.90)	0.01733	0.02760	2315	1503
2	0.00087 (0.54)	0.00017 (0.53)	0.00070 (0.85)	0.01676	0.02855	2377	1441
3	0.00057 (–065)	0.00066 (–0.63)	–0.00009 (–0.11)	0.01793	0.02670	2248	1570
4	0.00099 (0.77)	0.00001 (–0.74)	0.00098 (1.22)	0.01681	0.02819	2330	1488
5	0.00096 (0.70)	0.00007 (0.67)	0.00089 (1.12)	0.01702	0.02783	2301	1517
6	0.00046 (–0.29)	0.00081 (0.27)	–0.00035 (–0.46)	0.01775	0.02661	2191	1627
7	0.00107 (0.78)	0.00015 (–0.72)	0.00082 (1.29)	0.02055	0.02330	1918	1900
8	0.00130 (1.11)	0.00014 (–0.78)	0.00116 (1.64)	0.02026	0.02303	1533	2285
9	0.00118 (0.89)	0.00028 (–0.56)	0.00090 (1.27)	0.01978	0.02313	1399	2419
10	0.00112 (1.03)	–0.00004 (–0.86)	0.00116 (1.54)	0.01643	0.02733	2119	1699
11	0.00060 (–0.01)	0.00062 (0.01)	–0.00002 (–0.02)	0.01875	0.02508	2018	1800
12	0.00076 (0.25)	0.00046 (–0.23)	0.00030 (0.41)	0.02103	0.02282	1856	1962
13	0.00103 (0.62)	0.00046 (–0.27)	0.00057 (0.79)	0.01806	0.02321	1009	2809

X(b) and *X(s)* are the mean returns of the buy and sell days. *X*(*h*) is the mean return for the buy-and-hold strategy. *N(b)* and *N(s)*are the number of buy and sell days. *SD(b)* and *SD(s)* are the standard deviation of buy and sell days. The numbers in the parentheses are the t-statistics testing the difference of the mean buy and mean sell from the mean of buy and hold, and buy-sell from zero.

In order to illustrate the meaning of numbers in Table 1, let us choose the row of Model 1 which reports the results of moving average 20 (MA20) model as an example. We will be in the market (buy days) if the BOVESPA index is greater than MA20 and out of the market (sell days) if the BOVESPA index is less than or equal to MA20. The mean return difference between buy days and B&H strategy for Model 1 is .00120 (Or 0.120 % per day). To test whether this mean buy day return is different from the mean of the buy and hold strategy, we use Equation (3) to calculate the estimated t-statistic as 1.18. Since 1.18 is less than the critical value of 1.96, we therefore conclude that we cannot reject the null hypothesis that the mean buy returns equal the mean of the buy and hold strategy, in other words, this rule does not beat the market buy and hold strategy. The same conclusion for the mean return difference between sell days and B&H strategy is also reached, since –1.16 is greater than –1.96. We cannot reject the null hypothesis that the mean sell returns equals the mean of the buy and hold strategy. The t-stat for the mean buy minus mean sell is 1.90 which is less than 1.96. We also conclude that the null hypothesis of the equality of the mean buy days and mean sell days cannot be rejected. Columns 5 (SD (b)) and 6 (SD(s)) report the standard deviation of buy and sell days. Because SD(s) is greater than SD(b), it implies that the BOVESPA market is more volatile when the market is going down. Finally the number of buy days and sell days are reported in the last two columns. The next step is to investigate whether the double-indicator trading rules can beat the market or not.

Table 2. Double-indicator models

Models	X(b) –X(h)	X(s) –X(h)	X(b) –X(s)	SD(b)	SD(s)	N(b)	N(s)
14	0.00176	0.00020	0.00156	0.01626	0.02364	997	2821
	(1.84)	(–0.71)	(2.28)*				
15	0.00116	0.00001	0.00115	0.01609	0.02693	1989	1829
	(1.09)	(0.083)	(1.59)				
16	0.00118	–0.00012	0.00130	0.01651	0.02736	2138	1680
	(1.14)	(–0.96)	(1.72)				
17	0.00096	0.00050	0.0046	0.01683	0.02329	886	2932
	(0.53)	(0.19)	(0.65)				
18	0.00117	0.00042	0.00075	0.01501	0.02385	959	2859
	(0.94)	(–0.33)	(1.15)				
19	0.00114	0.00000	0.00114	0.01639	0.02695	2036	1782
	(1.05)	(–0.83)	(1.56)				
20	0.00109	–0.00003	0.00112	0.01647	0.02759	2175	1643
	(0.97)	(–0.83)	(1.47)				
21	0.00136	0.00041	0.0095	0.01567	0.02336	805	3013
	(1.14)	(–0.36)	(1.37)				
22	0.00157	0.00034	0.00123	0.01425	0.02363	821	2997
	(1.57)	(–0.47)	(1.87)				
23	0.00114	0.00001	0.00113	0.01642	0.02685	2020	1798
	(1.04)	(–0.82)	(1.54)				
24	0.00190	0.00030	0.00160	0.01906	0.02258	727	3091
	(1.63)	(–0.56)	(1.95)				

X(b) and *X(s)* are the mean returns of the buy and sell days. *X*(*h*) is the mean return for the buy-and-hold strategy. *N(b)* and *N(s)*are the number of buy and sell days. *SD(b)* and *SD(s)* are the standard deviation of buy and sell days. The numbers in the parentheses are the t-statistics testing the difference of the mean buy and mean sell from the mean of buy and hold, and buy-sell from zero. Asterisks denote statistical significance at the 5% level for a two-tailed test.

The results of Table 2 are again very weak. All the t-statistics for both the mean buy days and mean sell days are insignificant. We cannot reject the null hypothesis of the equality of mean buy returns or mean sell returns with the mean of buy and hold returns. There is only one exception, Model 14, the combination of Model 1 (MA20) and Model 7 (Fast Stochastic). The t-statistic of the difference between men buy days and mean sell days is 2.28 greater than 1.96. We reject the equality of the mean buy returns with the mean of sell returns. One possible explanation for the significant result is from the observation of numbers of days. When we use double-indicator trading rules, the numbers of buy days are significantly lower than the numbers of sell days. The longer period out of the market will certainly reduce the annual return even if the traders decide to be in the money market on those days. The overall results of Table 2 are still very weak to suggest that even using double-indicator trading rules the BOVESPA market, the weak form efficiency is still confirmed in the Brazilian stock market.

Table 3. Triple-indicator models

Models	*X(b) –X(h)*	*X(s) –X(h)*	*X(b) –X(s)*	*SD(b)*	*SD(s)*	*N(b)*	*N(s)*
25	0.00158	0.00035	0.00123	0.01429	0.02357	797	3021
	(1.58)	(–0.46)	(1.86)				
26	0.00148	0.00038	0.00110	0.01409	0.02360	795	3023
	(1.43)	(–0.41)	(1.68)				
27	0.00128	0.00049	0.00079	0.01657	0.02281	592	3226
	(0.87)	(–0.23)	(1.00)				
28	0.00170	0.00028	0.00142	0.01500	0.02364	879	2939
	(1.76)	(–0.58)	(2.11)*				
29	0.00171	0.00030	0.00141	0.01428	0.02365	831	2987
	(1.82)	(–0.55)	(2.15)*				
30	0.00153	0.00036	0.00127	0.01431	0.02359	806	3012
	(1.49)	(–0.44)	(1.76)				
31	0.00157	0.00035	0.00122	0.01431	0.02356	795	3023
	(1.56)	(–0.46)	(1.84)				
32	0.00166	0.00027	0.00139	0.01542	0.02366	923	2895
	(1.70)	(–0.59)	(2.07)*				

X(b) and *X(s)* are the mean returns of the buy and sell days. *X*(*h*) is the mean return for the buy-and-hold strategy. *N(b)* and *N(s)*are the number of buy and sell days. *SD(b)* and *SD(s)* are the standard deviation of buy and sell days. The numbers in the parentheses are the t-statistics testing the difference of the mean buy and mean sell from the mean of buy and hold, and buy-sell from zero. Asterisks denote statistical significance at the 5% level for a two-tailed test.

The triple-indicator trading rules are slightly better than the results of Tables 1 and 2. However, the overall results are still very weak. Similar to Tables 1 and 2, none of the mean buy and mean sell returns show significant t-statistics to beat the market buy and hold strategy. Although the t-statistics in Models 28, 29 and 32 show the significance for the difference between mean buy and mean sell returns, considering the much less days in the market compared with those out of market days, we are only 23%, 22 % and 24 % respectively in the market. If a trader does not choose any other alternative investment when out of the market, those out of the market days will contribute zero returns and will bring the annual returns lower.

In order to obtain unambiguous results to support weak form efficiency in Brazilian stock market, let us reconsider the four models, Model 14, 28, 29 and 32, showing significant t-test statistics in the difference of mean by days and mean sell days. When the models emit sell signal, a trader can be in the money market and earn money market interests. That is, when the model emits buy signal then we are in the stock market; when the model emits sell signal, we are in the money market. We can test whether this stock-money market strategy (SMM) beats the buy and hold strategy (B&H) or not.

We define the daily difference return (DDR) as the difference between the daily return of SMM strategy and the daily B&H return. The money market interest rates for SMM strategy are obtained from the DataStream's Brazilian overnight rate. The hypothesis testing for the mean of DDR, $X(DDR)$, is constructed as the following:

$H_0 : X(DDR)= 0$

$H_A : X(DDR)\neq 0$

$$t = \frac{X(DDR)}{\sqrt{\frac{Var(DDR)}{N}}}, \tag{4}$$

where *Var(DDR)* is the variance of daily difference returns and *N* is the total number of days. Table 4 reports the testing results for Models 14, 28, 29 and 32.

Table 4. Mean of daily difference returns

Models	*X(DDR)*	*SD(DDR)*
14	0.00022 (0.66)	0.02031
28	0.00017 (0.49)	0.02074
29	0.00015 (0.46)	0.02092
32	0.00017 (0.51)	0.02060

X(DDR) and *SD(DDR*) are the mean and the standard deviation of daily difference between the return of stock-money market strategy and the buy-and-hold strategy. The numbers in the parentheses are the t-statistics testing the equality of average daily difference from zero.

As we can see from Table 4, all the t-stats from Equation (4) are well below 1.96, the critical value of 5% significance. We cannot reject the null hypothesis that the mean return of the stock-money market strategy is different from the mean return of buy and hold strategy. All the four trading rules with multiple indicators still cannot beat the market. The weak form market efficiency is solidly confirmed in the Brazilian stock market.

5. Concluding Remarks

This paper confirms solidly the Weak-Form Efficient Market Hypotheses (WFEMH) for the Brazilian stock index (BOVESPA) over the period 5/1/1996 to 3/1/2011. We apply a variety of trading rules with single, double and triple indicators to support the non-predictive power of technical analysis. None of the trading rules can beat the buy and hold strategy, even the possible money market earning is considered while the investors are out of stock market. As Chong *et al.* (2010) noted, compared with the other BRIC countries, Brazil has a much longer history of stock market as one explanation of market efficiency. Our study also provides a better methodology to investigate the statistical results. When some trading rules show the predictive power to beat the buy and hold strategy, we need to adjust their mean returns by considering the possible interest earning from money market when the investors are out of the stock market. After doing so, the original profitable trading rules are very unlikely to perform better than the buy and hold strategy, especially for the multi-indicator models with a much shorter period in the stock market.

The limitation of our study is that the transaction costs are not considered. However, it will not alter the support of WFEMH in the Brazilian stock market. Transaction costs will even lower the mean returns of all kinds of trading rules to eliminate the predictive power. The future studies can be based upon our methodology to investigate the other emerging stock markets in a longer period. When the money market interest rates are relatively higher, the trading rules with multiple indicators are more unlikely to beat the market to confirm the WEFMH in countries like India, Russia and China. The efficiency of those emerging markets will assume greater importance in global investments as a result of regulatory reforms and removal of other barriers for the international equity investments.

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