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# Structural Change in the Stock Market Efficiency after the Millennium: The MACD Approach

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## Abstract

This paper studies the profitability of the Moving Average Convergence-Divergence (MACD) trading rule under three different crossing rules: the MACD zero line, the 9-day and 14-day signal lines. It is found that the trading rules perform well in the stock markets of Germany and Hong Kong. Our research also shows that generally the major stock markets around the world have become more efficient after the millennium.

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## I. Introduction

Technical analysis involves the study of historical prices in order to predict future price movements. It assumes that the information contained in historical prices is not correctly incorporated in current prices (Ellinger, 1971). Whether technical trading rules can generate excess returns has long been a controversial issue. A number of studies have suggested that market indicators alone cannot improve the prediction of the future prices (Neftci, 1991; Hudson *et al*., 1996; Mills, 1997). However, there are also studies that support technical trading rules (Treynor and Ferguson, 1985; Brock *et al*., 1992). Most of the earlier studies examine simple trading rules such as the moving average rule and the trading range break rule. Chong and Ng (2008) test the Moving Average Convergence-Divergence (MACD) rules on the London Stock Exchange FT30 Index and concluded that they can generate abnormal returns. Developed by Gerald Appel in the 1960s, the MACD is one of the simplest and most frequently applied trading rules in the market. In this paper, three signal lines of MACD will be evaluated in turn to see whether their associated trading rules are profitable in five major stock markets (US, Japan, UK, Germany, Hong Kong). We will also compare the market efficiency of these five markets before and after the millennium.

## II. Trading rules and Data

The MACD is calculated by subtracting the long exponential moving average (EMA) from the short EMA. The EMA is defined as:

$$EMA_t = \frac{2}{n} \times P_t + (1 - \frac{2}{n}) EMA_{t-1},$$

where $EMA_t$ is the exponential moving average at time $t$, $n$ is the window bandwidth, $P_t$ is the closing price on day $t$. The initial EMA is the n-day simple moving average of the series. In this paper, we apply the 12 and 26-day EMAs, the most commonly used short and long-term EMAs for the MACD trading rule (Murphy, 1999).

$$MACD_t = EMA_t^{12-day} - EMA_t^{26-day}.$$

Three different signal lines are examined in turn: 1) the MACD zero line; 2) the 9-day EMA of the MACD; and 3) the 14-day EMA of the MACD. A buy signal is triggered when the MACD crosses the signal line from below, while a sell signal is triggered when the MACD crosses the signal line from above. Specifically, we examine three trading rules:

Rule 1:

Buy: $MACD(t-1) < 0$ and $MACD(t) > 0$

Sell: $MACD(t-1) > 0$ and $MACD(t) < 0$

Rule 2:

Buy: $MACD(t-1) < EMA_{MACD}^{9-day}(t-1)$ and $MACD(t) > EMA_{MACD}^{9-day}(t)$

Sell: $MACD(t-1) > EMA_{MACD}^{9-day}(t-1)$ and $MACD(t) < EMA_{MACD}^{9-day}(t)$

Rule 3:

Buy: $MACD(t-1) < EMA_{MACD}^{14-day}(t-1)$ and $MACD(t) > EMA_{MACD}^{14-day}(t)$

Sell: $MACD(t-1) > EMA_{MACD}^{14-day}(t-1)$ and $MACD(t) < EMA_{MACD}^{14-day}(t)$

Short selling is not allowed in our study. A position that has been taken will not be reversed until the appearance of an opposite signal. For any signal at time t, we long or short the index at the closing price at t. Since there are about 250 trading days in a year, the performance is evaluated in terms of the annualized rate of return defined as:

$$\textit{Annual rate of return} = [(1+r_1)(1+r_2)(1+r_3)\cdots(1+r_m)]^{250/T} - 1$$

where $1+r_j = S(j)/B(j)$; $S(j)$ and $B(j)$ are selling and buying prices respectively in the $j$th transaction and $m$ is the number of transactions, and $T$ is the sample size. We examine the effectiveness of the each signal line by comparing their associated returns. The data series under study consists of the daily closing indices of five largest stock markets in the world extracted from DataStream. The sample details are as follows:

**Table 1. The five stock market indices and their sample period**

| Index | Countries | From | To |
|---|---|---|---|
| Dow Jones Industrials | USA | 1/1/1993 | 31/12/2007 |
| FTSE 100 | United Kingdom | 1/1/1993 | 31/12/2007 |
| DAX 30 Performance | Germany | 1/1/1993 | 31/12/2007 |
| Nikkei 225 Stock Avg. | Japan | 1/1/1993 | 31/12/2007 |
| Hang Seng Index | Hong Kong | 1/1/1993 | 31/12/2007 |

## III. Results and Conclusion

Table 2 shows the annual rate of return (in percentage) generated by three trading rules based on the Moving Average Convergence-Divergence and the buy-and-hold strategies. The figures in the parentheses are the number of transactions. The performance of each trading rule is listed in the table. For each index, the highlighted figure is the highest rate of return. If there is more than one highest return, the one with the smallest number of transaction will be highlighted. From our findings, the Moving Average Convergence-Divergence rule performs well in the stock markets of Germany and Hong Kong. All three trading rules Hang Seng Index generate a double-digit annual return. The zero-line crossing is found to be the most profitable rule for the DAX 30, Dow Jones Industrials and FTSE 100. The rule of 9-day signal line is found to be most profitable for the Nikkei 225, and the rule of 14-day signal line is the most profitable rule for the Hang Seng Index.

**Table 2. The average rate of return for MACD and the number of transactions**

| **Index Names** | **MACD Zero Line** | | **9-day Signal Line** | | **14-day Signal Line** | |
|---|---|---|---|---|---|---|
| Dow Jones Industrials | **4.04%** | (69) | 2.40% | (177) | 3.80% | (147) |
| FTSE 100 | **0.97%** | (73) | -3.03% | (192) | -3.36% | (160) |
| DAX 30 Performance | **12.24%** | (52) | 1.26% | (184) | 5.06% | (153) |
| Nikkei 225 Stock Avg. | 1.10% | (67) | **1.12%** | (160) | 0.60% | (133) |
| Hang Seng Index | 13.41% | (58) | 11.99% | (162) | **13.79%** | (120) |

To investigate whether there is any change in the market efficiency, we divide the whole sample into two sub-samples using the year 2000 as a cut-off point. The millennium as the cut-off year is a nature choice for three reasons: First, it is just two years after the Asian Financial Crisis; Second, it is the year when the internet bubble started to collapse (Chong and Chan, 2008); Third, it is also close to the date of the 911 attack.

Table 3a and 3b show the returns of the MACD rules before and after the millennium. For the stock market of the Germany and the United Kingdom, the zero-line crossing rule is the most profitable rule in both periods. In other stock markets, there is no trading rule that can consistently outperform others in both subsamples. As the market develops, it should become more efficient. Note that the returns after the year 2000 are generally smaller than those before the year 2000. This implies that the market has become more efficient. In a nutshell, we find that the Moving Average

Convergence-Divergence perform well in the stock markets of Germany and Hong Kong. Our research also shows that generally the major stock markets have become more efficient after the millennium.

**Table 3a: The average rate of return for Period I: 1/1/1993 - 31/12/1999**

| Index Names | MACD Zero Line | 9-day Signal Line | 14-day Signal Line |
|---|---|---|---|
| Dow Jones Industrials | **10.65%** | 4.37% | 7.28% |
| FTSE 100 | **3.83%** | 0.51% | -0.55% |
| DAX 30 Performance | **15.27%** | 4.22% | 9.19% |
| Nikkei 225 Stock Avg. | 1.69% | 0.28% | **3.49%** |
| Hang Seng Index | 15.67% | 20.97% | **23.76%** |

**Table 3b: The average rate of return for Period II: 1/1/2000 - 31/12/2007**

| Index Names | MACD Zero Line | 9-day Signal Line | 14-day Signal Line |
|---|---|---|---|
| Dow Jones Industrials | -1.99% | 1.09% | **1.20%** |
| FTSE 100 | **-2.13%** | -5.73% | -5.29% |
| DAX 30 Performance | **5.27%** | -1.84% | 0.85% |
| Nikkei 225 Stock Avg. | 0.19% | **2.17%** | -1.48% |
| Hang Seng Index | **9.32%** | 5.56% | 5.70% |

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