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US Stock Market Efficiency: EMH or AMH?

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Abstract. This paper adopts a forecasting method to shed light on efficiency of the US stock market using the S&P500 index in the past 30 years. Daily data is grouped into 30 subsamples. The modified Diebold-Mariano (MDM) test is used to compare the forecasting performances of the random walk model and the Autoregressive Integrated Moving Average (ARIMA) model to show which is a better description of the daily returns of the S&P 500. The results show that the ARIMA model persistently outperforms the random walk model, which suggests that the US market is not in a weak form of efficiency during the sample period. On the other hand, it is also shown that whether the US stock market is efficient or not somehow depends on how investors evaluate their losses.

1. Introduction

The Efficient Market Hypothesis (EMH), put forward by Eugene Fama (1970), proposes three forms of efficiency of the financial markets, namely the strong, semi-strong and weak forms of efficiency. When a market is in strong form of efficiency, all public and private information is reflected in asset prices, which can be depicted by the random walk model. When a market is in semi-strong form of efficiency, all public information is reflected in asset prices. When a market is in weak form of efficiency, historical information is incorporated in asset prices and hence it is impossible to predict asset prices based on historical data. So far, there is a large number of researches conducted to test the EHM. For instance, Sewell (2012) analyzes daily, weekly, monthly and annual Dow Jones Industrial Average log returns. The standard run test shows that daily returns do not appear to be independent and thus rejects the efficient hypothesis. However, EMH is shown to be valid with evidence from weekly, monthly and annual returns. The author further suggests that technical analysis to the market do not outperform the market itself. Yadirichukwu and OgochukwuIn(2014) examine the monthly stock market indexes of Nigeria between 1984 and 2012 to test the weak form of efficiency. They use unit root test and t-test to examine the validity of EMH. The result of the study fails to conform to the random walk model based on the annual result and thus indicates that the Nigeria stock market is not in a weak form of efficiency. Yet, there are traits of market efficiency based on monthly data of Nigeria stock returns. Hence, their empirical evidence supports the EMH.

Since recent studies, especially those use higher-frequency data such as daily data, show that the EMH does not perform well, Lo (2004) proposes the Adaptive Market Hypothesis (AMH). The intuition behind is that opportunities arise in the market, making the market inefficient, but they can be exploited by arbitragers, who restores the efficiency of the market. Thus, the market will exhibit efficiency and inefficiency patterns in turn. Over the latest decade, Lo's AMH has gained increasing interest in financial studies. Urquhart and Hudson (2013) examine the US, UK and Japanese stock markets using yearly samples of five years by applying both linear and non-linear tests. The results of linear tests, including autocorrelation, runs and variance ratio tests, show variations on the magnitude of dependence over time and nonlinear tests results show a strong dependence overall. They thus conclude that the AMH is a better description of the stock return. Gourishankar and Kumari (2014) study the stock market of India to see if AMH serves as a better description of its behaviors. The results of linear tests, including autocorrelation, runs and multiple variance ratio test, results show that there are cyclical interchanges between efficient market and inefficient market. Similar with Urquhart and Hudson's conclusion, they claim that the nonlinear tests – Mcleod-Li, ARCH-LM, Hinich bicorrelation and BDS test show stronger trends of inefficiency. They finally suggest that Indian stock market is getting increasingly efficient. Shi, Jiang and Zhou (2015) apply the wild bootstrap automatic variance ratio test and the generalized spectral test to study the Chinese stock market. They find that there is alternation between random walk behaviors and predictability of stock returns. They suggest that the strongest predictability appears when the market is in turmoil, for which they conclude the behavior of Chinese stock market is consistent with the AMH.

Existing literature use similar linear tests, such as the runs test, autocorrelation and multiple variance ratio test, to examine the AMH. This paper, however, uses a forecasting method to analyze the daily returns of the S&P500 index in the past 30 years to test the AMH. The S&P500 index returns are divided by year into 30 subsamples to test whether the Autoregressive Integrated Moving Average (ARIMA) model outperforms the random walk model in each subsample by the modified Diebold-Mariano (MDM) test. The results show that whether the US stock market is efficient or not somehow depends on how investors evaluate their losses. In addition, the result also seems to agree that the ARIMA model persistently performs better than the random walk in each subsample in terms of out-of-sample forecasting performance. Therefore, it is concluded that the US market is not in a weak form of efficiency when subject to the significance level used to reject the null hypothesis. This paper contributes to the existing literature by applying a forecasting method to the study of US stock market efficiency.

The rest of the paper is divided into four sections. Section 2 explains the data and method used in this study. In section 3, empirical results are presented and explained, followed by the last section, section 4, where a short conclusion is provided.

2. Data and Methodology

The data used in this paper are daily returns of the S&P500 index of from October 19th, 1988 to October 18th, 2018, which can be calculated by the following formula:

$$r_t = \ln(P_t) - \ln(P_{t-1})$$

where r_t stands for the daily return of the S&P 500 index at day t; and P_t stands for the index price of day t.

Once the return is calculated, the whole sample period is divided into 30 subsamples by year. Table 1 shows the summary statistics of the daily return in each subsample period. Most returns in the subsamples are negatively skewed, which is consistent with the results of existing literature.

In each subsample, the out-of-sample performance of the random walk model is compared with that of the ARIMA model using the MDM test. The random walk model can be characterised by the following equation:

$$F_t = \alpha + D_{t-1} + \varepsilon_t$$

where F_t stands for the forecasted value at time t, D_{t-1} is the observation at time $t-1$, and ε_t is the error term. The random walk model implies that the best prediction of tomorrow's price is today's price. Therefore, if it outperforms other forecasting models, the market behavior is consistent with the EMH.

The Autoregressive Integrated Moving Average (ARIMA) model is given as follows:

$$F_t = \alpha_1 D_{t-1} + \alpha_2 D_{t-2} + \cdots + \alpha_p D_{t-p} + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \cdots + \theta_q \varepsilon_{t-q}$$

where F_t stands for the forecasted value at time t, D_{t-1} is the observation at time $t-1$, p stands for the number of lags, and q stands for the number of moving-average terms.

Before using the ARIMA model, the time series are checked for stationarity using the Augmented Dicky-Fuller (ADF) test. If the time series is not stationary, difference is taken until the series becomes stationary. The modified Diebold-Mariano (MDM) test is used to compare the forecasting performances of the random walk model and the ARIMA model. The test statistics can be calculated by the following equation:

$$MDM = T^{-1/2}[T + 1 - 2k + T^{-1}k(k-1)]^{1/2}DM$$

where T represents the number of forecasting errors, k represents the forecasting horizon, and DM is the Diebold-Mariano test statistic.

Table 1 Summary Statistics

Start Date	End Date	Obs	Mean	StandardDev	Skewness	Kurtosis
10/19/88	10/18/18	7827	0	0.01	-0.29	9.49
10/19/88	10/18/89	261	0	0.01	-1.77	13.73
10/19/89	10/18/90	261	0	0.01	0.4	0.94
10/19/90	10/18/91	261	0	0.01	- 0.24	0.93
10/21/91	10/16/92	260	0	0.01	-0.26	3.16
10/19/92	10/18/93	261	0	0.01	-0.09	2.35
10/19/93	10/18/94	261	0	0.01	-0.35	1.78
10/19/94	10/18/95	261	0	0.01	-0.05	1.57
10/19/95	10/18/96	262	0	0.01	-0.72	2.12
10/21/96	10/17/97	260	0	0.01	-0.04	0.7
10/20/97	10/16/98	260	0	0.01	-0.74	5.88
10/19/98	10/15/99	260	0	0.01	-0.06	-0.28
10/18/99	10/18/00	263	0	0.01	-0.11	2.24
10/19/00	10/18/01	261	0	0.01	0.13	1.25
10/19/01	10/18/02	261	0	0.02	0.38	0.97
10/21/02	10/17/03	260	0	0.01	0.11	0.23
10/20/03	10/18/04	261	0	0.01	-0.1	-0.12
10/19/04	10/18/05	261	0	0.01	-0.03	-0.16
10/19/05	10/18/06	261	0	0.01	0.18	1
10/19/06	10/18/07	261	0	0.01	-0.66	3.09
10/19/07	10/17/08	261	0	0.01	-0.32	7.54
10/20/08	10/16/09	261	0	0.01	-0.03	2.39
10/19/09	10/18/10	261	0	0.01	-0.22	1.67
10/19/10	10/18/11	261	0	0.01	-0.82	4.93
10/19/11	10/18/12	262	0	0.01	0.16	2.24
10/19/12	10/18/13	261	0	0.01	-0.37	1.2
10/21/13	10/17/14	260	0	0.01	-0.68	1.36
10/20/14	10/16/15	260	0	0.01	-0.26	2.65
10/19/15	10/18/16	262	0	0.01	-0.35	1.39
10/19/16	10/18/17	261	0	0.01	0.02	3.72
10/19/17	10/18/18	261	0	0.01	-1.24	5.09

Notes: this table shows the summary statistics of the daily returns of the S&P500 index in each subsample period.

3. Empirical Results

Table 2 summarizes the results of the MDM test. A positive test statistic shows that the ARIMA model provides better out-of-sample performance than the random walk model while a negative one indicates that the random walk model outperforms the ARIMA model. A significant MDM test statistic suggests that such outperformance of one forecasting model over another is statistically significant. From the table, we can see that if the power 1 loss function is used in the MDM test, all the test statistics are positive and almost all of them are significant at the 1% significance level. This suggests that the ARIMA model persistently outperforms the random walk model with evidence from the power 1 loss function, which implies that the US stock market is not in a weak form of efficiency persistently. However, when the power 2 loss function is used, the MDM test statistics of period 1 is significant at the 10% significance level while those of periods 10, 25, 27 and 30 are significant at the 5% level, with the rest significant at the 1% level. If the 1% significance level is adopted as the rejection criterion of the null hypothesis, result from the power 2 loss function seems to imply that there is an AMH consistent pattern of the US stock market. Therefore, the results seem to suggest that whether the US stock market is efficient or not somehow depends on how investors evaluate their losses. If they value their losses more and use the power 2 loss function, then the stock market is likely to show an AMH consistent pattern whereas if they value their losses less and use the power 1 function, then the stock market is likely to be inefficient.

Table 2 Modified Diebold-Mariano (MDM) Test Results

Period	Start Date	End Date	Power 1	Power 2	Efficiency
1	10/19/88	10/18/89	3.4404***	1.466*	Inefficient/Weakly Efficient
2	10/19/89	10/18/90	2.9628**	2.604***	Inefficient
3	10/19/90	10/18/91	4.0588***	2.9418***	Inefficient
4	10/21/91	10/16/92	4.8609***	3.8144***	Inefficient
5	10/19/92	10/18/93	5.3884***	4.5236***	Inefficient
6	10/19/93	10/18/94	3.9266***	3.0117***	Inefficient
7	10/19/94	10/18/95	4.803***	3.8498***	Inefficient
8	10/19/95	10/18/96	2.4487***	2.5122***	Inefficient
9	10/21/96	10/17/97	3.5194***	3.6592***	Inefficient
10	10/20/97	10/16/98	3.4852***	2.3399**	Inefficient
11	10/19/98	10/15/99	3.9424***	3.8447***	Inefficient
12	10/18/99	10/18/00	4.0002***	3.0989***	Inefficient
13	10/19/00	10/18/01	3.5777***	3.0858***	Inefficient
14	10/19/01	10/18/02	3.2455***	3.7297***	Inefficient
15	10/21/02	10/17/03	6.2301***	6.0526***	Inefficient
16	10/20/03	10/18/04	5.1749***	4.865***	Inefficient
17	10/19/04	10/18/05	5.1954***	4.7572***	Inefficient
18	10/19/05	10/18/06	5.2264***	3.5342***	Inefficient
19	10/19/06	10/18/07	6.7024***	4.6822***	Inefficient
20	10/19/07	10/17/08	4.3539***	2.9818***	Inefficient
21	10/20/08	10/16/09	3.547***	3.3807***	Inefficient
22	10/19/09	10/18/10	5.0523***	4.3108***	Inefficient
23	10/19/10	10/18/11	3.8064***	2.8539***	Inefficient
24	10/19/11	10/18/12	3.775***	3.4142***	Inefficient
25	10/19/12	10/18/13	2.4283***	1.8361**	Inefficient
26	10/21/13	10/17/14	5.6992***	3.6268***	Inefficient
27	10/20/14	10/16/15	3.0261***	2.0219**	Inefficient
28	10/19/15	10/18/16	4.9559***	2.9865***	Inefficient
29	10/19/16	10/18/17	5.07***	3.908***	Inefficient
30	10/19/17	10/18/18	2.8352***	2.1356**	Inefficient

Notes: This table shows the modified MDM test results. A positive MDM test statistic indicates that ARMIA model outperforms that random walk.
Significance notes: *** 1% significance level, ** 5% significance level, * 10% significance level.

4. Conclusion

This paper studies the market efficiency of the US stock market. The results suggest that whether the US stock market is efficient or not somehow depends on how investors evaluate their losses. When the power 1 function is applied, indicating that investors value losses less, the result seems to suggest that the stock market is inefficient. However, when the power 2 loss function is applied, indicating that investors value losses more, evidence seems to suggest that the stock market shows an AMH consistent pattern. Nevertheless, the empirical evidence implies that the US stock market is not in a weak form of efficiency if the 5% significance level is used as the rejection criterion of the null hypothesis. This result is consistent with that of Sewell (2012), who shows that the daily US stock returns are not in a weak form of efficiency.

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