THE EFFICIENT MARKET HYPOTHESIS

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SIGNATURE PAGE

THESIS: The Efficient Market Hypothesis

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ABSTRACT

The paper attempts testing the random walk hypothesis, which the strong form of the Efficient Market Hypothesis. The theory suggests that stocks prices at any time “fully reflect” all available information (Fama, 1970). So, the price of a stock is a random walk (Enders, 2012).
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INTRODUCTION

One of the most controversial hypotheses in the world of economics, social studies and finance is the efficient market hypothesis (EMH) (Sewell, 2012). Many studies were done to reach severely diverse and conflicting results (Sewell, 2012). The EMH basically says that the security prices at any time “fully reflect” all available information (Fama, 1970).

A prominent method to study it empirically is the random walk model (Enders, 2012). It implies that daily changes in stocks’ prices should have a mean of zero (Enders, 2012). The model explains that if market participants knew that they can make a profit by buying a certain share one day and selling it the next day, they will all do it and affect the price (Enders, 2012). On the other hand, if market participants expect the price to go down, they will sell it (Enders, 2012).

This paper will attempt to apply a model mentioned by Walter Enders in his book, Applied Econometric Time Series, under the random walk hypothesis section (Enders, 2012). The empirical aim of it was to decide whether prices of stock fully explain all available information (Enders, 2012).
HISTORY

The EMH was highly discussed and talked about through the years. This section mentions only few points of the large history of it.

Early Literature

It was claimed that the idea was first introduced in the 16th century by the Italian mathematician Gerolamo Cardano in (The Book of Games of Chance) (Cardano, 1564). Then, a French broker named Jules Regnault in 1863 noticed that the longer you keep a security, the more you have risks of winning or losing (Regnault, 1863). He also observed that the price deviation is proportional to the square root of time (Regnault, 1863). Furthermore, a British physicist, Lord Rayleigh, recognized the idea of a random walk, which is a mathematical form of a path that consists of random steps, via his work on sound vibrations (Rayleigh, 1880). In 1889, George Gibson published a book under the name of The Stock Markets of London, Paris and New York, where he spoke about efficient markets in a clear manner (Gibson, 1889).

Then, it was discussed by Louis Bachelier, a French mathematician, in his PhD thesis The Theory of Speculation in 1900 (Bachelier, 1900). His work was ahead of his time and was ignored until Leonard Jimmie Savage rediscovered it in 1955 in Chicago or Yale library (Sewell, 2011). Bachelier introduced the mathematics and statistics of Brownian motion, which is a mathematical model describing random movements, before Einstein did in 1905 (Sewell, 2011). In addition, he concluded that a speculator has a
mathematical expectation of number zero 65 years before Samuelson (Samuelson, 1965) (Sewell, 2011). Many other discoveries and theories were attributed to him, which can be checked in his thesis (Bachelier, 1900).

1920-1960

Later in 1923, the famous John Maynard Keynes talked about the idea; saying that investors win or lose because of risk taking, not for knowing better than the market (Keynes, 1923). In 1933, the founder of Econometric society and its journal Econometrica, Alfred Cowles the 3rd did a study and founded that securities’ forecasters cannot forecast (Cowles, 1933). In his book “General Theory of Employment, Interest and Money” published in 1936, Keynes compared the stock market to a beauty contest and said that ‘animal spirits’ control investors’ decisions (Keynes, 1936).

A year after, Eugen Slutzky proofed that sum of independent random variables can create cyclical processes (Slutzky, 1937). However, in 1937, Cowles and Jones found inefficiencies in the hypothesis through the evidence of serial correlation in averaged time series indices of prices of stocks (Cowles and Jones, 1937). Their paper is considered the only one before 1960 to witness the inefficiency (Sewell, 2011).

Milton Friedman had his opinion about it. In 1953, He said that EMH can be applied even when the trading strategies of investors are correlated because of arbitrage (Friedman, 1953). In 1960, Larson created a new use of time series analysis, the distribution of price changes has almost a normal distribution for the central 80% of the
data, with large number of extreme values (Larson, 1960). In 1962, Mandelbrot suggested that the tails of the returns distribution have a power law, that is a relationship between two quantities, in which one quantity changes as a power of the other (Mandelbrot, 1962). Also, the famous Jack Treynor wrote a manuscript that went unpublished called 'Toward a theory of market value of risky assets’ (Treynor, 1962). That paper is considered the first on the Capital Asset Pricing Model (CAPM) and is commonly not referenced accurately (Sewell, 2011).

In 1963, Granger and Morgenstern did a spectral analysis on market prices and concluded that short-run fluctuations of the series follow the random walk hypothesis, though long-run movements do not (Granger and Morgenstern, 1963). They also found that business cycles were less significant or not at all (Granger and Morgenstern, 1963). The following years witness many books written about the EMH, one of the most important is Cootner’s, The Random Character of Stock Market Prices, published in 1964 (Cootner, 1964). The book is a collection of papers by Roberts, Bachelier, Cootner, Kendall, Osborne, Granger and Morgenstern, Staiger, Fama and many others (Cootner, 1964). In the same year, Sharpe published his crucial work on the CAPM that won him a Nobel prize (Sharpe, 1964).

Economist Paul Samuelson published the 'Proof that properly anticipated prices fluctuate randomly(Samuelson, 1965). He stressed that idea of martingale, which is a model of a fair game in which the predictability of future prices does not depend on the knowledge of past events, instead of a random walk (Samuelson, 1965).
Eugene Fama’s Work

Nevertheless, it was not until 1965 when well-known Nobel Price winner Professor Eugene Fama developed the EMH in his Ph.D. at the University of Chicago Booth School of Business (Fama, 1965). He defined the word “efficient” for the first time and found that stock market prices follow a random walk (Fama, 1965).

Fama published a detailed review of several forms and theories of the EMH in the 1970s (Fama, 1970). His paper is considered the definitive paper on EMH (Sewell, 2011). On that paper, The EMH was categorized into three forms; strong, semi strong and weak, which Fama attributed to economist Harry Roberts (Fama, 1970).

1- The strong form of the hypothesis states that the market prices reflect all information, which means no investor has a monopolistic information relevant to price setting (Fama, 1970).

2- The semi strong form suggests that stock prices reflect available public information only, and that there is private information hidden from common investors (Fama, 1970).

3- The weak form states that stock prices cannot be predicted via historical prices. As far as the empirical studies, they led to the development of the theoretical part (Fama, 1970).

1990-2000

The theory was popular until the rise of behavioral finance in the 1990s (Fox, 2002). Many economists went to prove that the theory is unreliable, one of which is
THEORY

Although the main definition of EMH is universally agreed upon, many interpretations and theories were developed around it (Fama, 1970). One of the most useful resources in this subject is Fama’s 1970 Efficient Capital Markets: A Review of Theory and Empirical Work, which discussed many of the theories in details (Fama, 1970). These empirical studies include expected return models, the submartingale model, the random walk model and many others (Fama, 1970).

He described the random walk model following two assumptions. First, that successive price changes (or returns) are independent (Fama, 1970). Second, that they have to be identically distributed (Fama, 1970). These two hypothesis form the model, which suggests that the independent random variable has identical conditional and marginal probability distributions (Fama, 1970).

The same theory applied in this paper, depending on a model mentioned by Walter Ender in his book Applied Econometric Time Series (Enders, 2012). It implies that the change in price of a stock from one day to the next is absolutely random, which means daily changes in stocks’ prices should have a mean of zero (Enders, 2012). It is applied through the stochastic difference equation, which is a mathematical equation that links a function of one or more random variables to their derivatives (Enders, 2012). The stochastic difference equation that describes the EMH in this paper is (Enders, 2012):

\[ y_t = y_{t-1} + \varepsilon_t \] (1)
where $y_t =$ the price of a share of stock in day $t$

$y_{t-1} =$ the price of the share of stock on the day before

$\varepsilon_t =$ a random error term with the expected value of zero

If we accept the null, it can be written as (Enders, 2012):

$$\triangle y_t = \varepsilon_t \ (2)$$

However, the regression will run as (Enders, 2012):

$$\triangle y_t = \alpha_0 + \alpha_1 y_{t-1} + \varepsilon_t \ (3)$$

The hypothesis is (Enders, 2012):

$H0: \alpha_0 = \alpha_1 = 0$

$H1: \alpha_0 = \alpha_1 \neq 0$

The rejection of the null reject the theory (Enders, 2012). Also, the mean of the error has to equal zero to invalidate the theory (Enders, 2012).

Furthermore, Fama argued that the model is an extension of the “fair game” efficient markets model (Fama, 1970). Hence, the random walk model makes a more detailed statement about the economic surrounding (Fama, 1970). The “fair game” model states that the conditions of market equilibrium can be described in terms of expected returns (Fama, 1970). The random walk goes through the stochastic process producing
returns (Fama, 1970). It simply appears when two conditions are combined in an economic environment to reach equilibrium; the development of investors’ tastes and the process generating new information (Fama, 1970). This equilibrium then witnesses the repetition of return distributions through time (Fama, 1970).
The DATA

The data is from Yahoo! Finance; historical quarterly values were taken from 1/2/1981 to 12/2/2013, a total of 396 prices (Finance).

The stock is pretty volatile as seen in figure 1. The vertical axis is the change in the price of Apple Inc. stock and the horizontal axis is time.

Figure 1. The change in Apple Inc. stock price from 1981-Q1 to 2013-Q4

The stock was pretty stationary until 2000. A big peak around 2000 was witnessed because of the tech bubble (Petruno, 2011). Thus, a huge drop can be seen around 2001, which is interpreted as the tech bubble burst (Petruno, 2011). The stock then turned more volatile as the financial crisis hit in 2007 (Petruno, 2011). Also, the strong peak in early
2011 was because Apple reported its best earning quarter ever (Petruno, 2011). However, later that year the spiritual founder of Apple Steve Jobs has died causing a big drop (Petruno, 2011).
THE MODEL

Following equation 3, the model suggests that the price of Apple Inc. stock in period t have to be equal to last period’s price with a white-noise term (Enders, 2012). The method used is Ordinary Least Square (OLS), which a simple linear relationship:

\[ \Delta \text{APPL}_t = \alpha_0 + \alpha_1 \text{APPL}_{t-1} + \epsilon_t \] (4)

where \( \Delta \text{APPL}_t \) = the change in the price of a share of Apple Inc. stock in day t

\( \text{APPL}_{t-1} \) = the price of the Apple Inc. share of stock on the day before

\( \epsilon_t \) =a random error term with the expected value of zero

Stationarity

For the random walk model, the variance is constant (Enders, 2012). In addition, the autocorrelation function for a random walk model will have a tendency to decline (Enders, 2012). Therefore, using an autocorrelation function to create a stationary process will have no application with an autoregressive coefficient that is near zero (Enders, 2012).

Autocorrelation

The model is preferred to have no serial correlation (Sewell, 2012). Many economists like Fama indicated the exhibition of serial correlation in stocks prices (Fama, 1970). However, detrending the data is not the solution because the results will not
change accordingly (Sewell, 2012).
EMPIRICAL STUDY

The results of the OLS regression of equation 5 in table 1.

\[ \Delta \text{APPL}_t = \alpha_0 + \alpha_1 \text{APPL}_{t-1} + \varepsilon_t \] (5)

Table 1

The Random Walk OLS Regression

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.210063</td>
<td>0.160029</td>
<td>1.312650</td>
<td>0.1916</td>
</tr>
<tr>
<td>APPL(-1)</td>
<td>-0.023156</td>
<td>0.023453</td>
<td>-0.987309</td>
<td>0.3253</td>
</tr>
</tbody>
</table>

R-squared     | 0.007500    | Mean dependent var | 0.074656 |
Adjusted R-squared | -0.000194 | S.D. dependent var   | 0.943745 |
S.E. of regression | 0.943836  | Akaike info criterion | 2.737422 |
Sum squared resid | 114.9167  | Schwarz criterion    | 2.78318 |
Log likelihood  | -177.3011  | Hannan-Quinn criter. | 2.755259 |
F-statistic     | 0.974778   | Durbin-Watson stat   | 1.786809 |
Prob(F-statistic) | 0.325340 |

The intercept and the coefficient in the regression are not significant, which implies accepting the null:

\[ H_0: \alpha_0 = \alpha_1 = 0 \]

\[ H_1: \alpha_0 = \alpha_1 \neq 0 \]
This means that the EMH on its strongest form does apply to this stock. The probability of the intercept is 0.19, that shows the insignificance of it, and the t-statistic is 1.3 that is low. The coefficient’s probability 0.3 and the t-statistic is -0.98, this means that the price of yesterday’s stock does not explain the change of today’s price. Therefore, accepting the null means the change in the price of the stock from one day to the next is absolutely random, which means daily changes in Apple stock’s price should have a mean of zero (Enders, 2012).

Since we accepted the null, we concluded that the change in the stock price is a random walk, which is non-stationary. Therefore, a stationarity test is not necessary (Enders, 2012). The serial correlation here is not significant as tested using Breusch-Godfrey test in table 2.
Table 2

Breusch-Godfrey test

Breusch-Godfrey Serial Correlation LM Test:

<table>
<thead>
<tr>
<th>F-statistic</th>
<th>1.792755</th>
<th>Prob. F(2,127)</th>
<th>0.1707</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obs*R-squared</td>
<td>3.596892</td>
<td>Prob. Chi-Square(2)</td>
<td>0.1856</td>
</tr>
</tbody>
</table>

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 05/18/14   Time: 20:25
Sample: 1981Q2 2013Q4
Included observations: 131
Presample missing value lagged residuals set to zero.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-0.014332</td>
<td>0.167264</td>
<td>-0.085688</td>
<td>0.9318</td>
</tr>
<tr>
<td>APPL(-1)</td>
<td>0.002421</td>
<td>0.024859</td>
<td>0.097395</td>
<td>0.9226</td>
</tr>
<tr>
<td>RESID(-1)</td>
<td>0.111394</td>
<td>0.091077</td>
<td>1.223078</td>
<td>0.2236</td>
</tr>
<tr>
<td>RESID(-2)</td>
<td>-0.136508</td>
<td>0.091626</td>
<td>-1.489829</td>
<td>0.1387</td>
</tr>
</tbody>
</table>

R-squared 0.027457 Mean dependent var 7.29E-17
Adjusted R-squared 0.004484 S.D. dependent var 0.940199
S.E. of regression 0.938089 Akaike info criterion 2.740115
Sum squared resid 111.7614 Schwarz criterion 2.827907
Log likelihood -175.4775 Hannan-Quinn criter. 2.775789
F-statistic 1.195170 Durbin-Watson stat 2.008041
Prob(F-statistic) 0.314377
THE VALUE OF THE HYPOTHESIS

A major field of computer applications in economics was time series (Bodie, Kane, and Marcus, 2014). Predicting the future with past values was popular and made sense especially to business cycle theorists (Bodie et al., 2014). A clear way to study that was by analyzing stock prices, with the assumption that they reflect companies’ performances and the overall health of the economy (Bodie et al., 2014). Therefore, studying the EMH is crucial not only for stock prices, but for many time series variables as well.

The hypothesis is very important in the world of investment. Many economists believe that investors tend to overreact to information (Jegadeesh and Titman, 1993). Therefore, testing the hypothesis check whether investors overreact to past values or not (Jegadeesh and Titman, 1993). Also, some argued that the situation varies when holding strong performing portfolios against low performing ones (Jegadeesh and Titman, 1993).

The hypothesis is considered one of the most talked about theories in finance and economics. It was and still is tested in various methods and interpretations.
CONCLUSION

The efficient market hypothesis remains one of the most important theories in economics. It claims that capital markets’ prices are efficient and unbiased in reflecting information (Fama, 1970). Although there is no real market that can reflect exactly and fully market information, a hypothesis is asymptotically true in social sciences and economics is one of them (Sewell, 2011).

In this study, we accept the strong form of the theory. Thus, prices of Apple Inc. stock fully reflects available information. The price since 1981 went through major changes along with the performance of the company. That is to say, it was not always a good performing company. Nevertheless, the hypothesis is accepted in this analysis.
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