

Measuring weak-form market efficiency



**ASSIGN
BUSTER**

Measuring Weak-form Market Efficiency

ABSTRACT

This paper tests weak-form efficiency in the U. S. market. Both daily and monthly returns are employed for autocorrelation analysis, variance ratio tests and delay tests. Three conclusions are reached. Firstly, security returns are predictable to some extent. While individual stock returns are weakly negatively correlated and difficult to predict, market-wide indices with outstanding recent performance show a positive autocorrelation and offer more predictable profit opportunities. Secondly, monthly returns follow random walk better than daily returns and are thus more weak-form efficient. Finally, weak-form inefficiency is not necessarily bad. Investors should be rewarded a certain degree of predictability for bearing risks.

Efficient market hypothesis (EMH), also known as “ information efficiency”, refers to the extent to which stock prices incorporate all available information. The notion is important in helping investors to understand security behaviour so as to make wise investment decisions. According to Fama (1970), there are three versions of market efficiency: the weak, semistrong, and strong form. They differ with respect to the information that is incorporated in the stock prices. The weak form efficiency assumes that stock prices already incorporate all past trading information. Therefore, technical analysis on past stock prices will not be helpful in gaining abnormal returns. The semistrong form efficiency extends the information set to all publicly available information including not only past trading information but also fundamental data on firm prospects. Therefore, neither technical analysis nor fundamental analysis will be able to produce abnormal returns.

Strong form efficiency differs from the above two in stating that stock prices not only reflect publicly available information but also private inside information. However, this form of market efficiency is always rejected by empirical evidence.

If weak-form efficiency holds true, the information contained in past stock price will be completely and instantly reflected in the current price. Under such condition, no pattern can be observed in stock prices. In other words, stock prices tend to follow a random walk model. Therefore, the test of weak-form market efficiency is actually a test of random walk but not vice versa. The more efficient the market is, the more random are the stock prices, and efforts by fund managers to exploit past price history will not be profitable since future prices are completely unpredictable. Therefore, measuring weak-form efficiency is crucial not only in academic research but also in practice because it affects trading strategies.

This paper primarily tests the weak-form efficiency for three stocks-Faro Technologies Inc. (FARO), FEI Company (FEIC) and Fidelity Southern Corporation (LION) and two decile indices-the NYSE/AMEX/NASDAQ Index capitalisation based Deciles 1 and 10 (NAN D1 and NAN D10). Both daily and monthly data are employed here to detect any violation of the random walk hypothesis.

The remainder of the paper is structured in the following way. Section I provides a brief introduction of the three firms and two decile indices. Section II describes the data and discusses the methodology used. Section III

presents descriptive statistics. Section IV is the result based on empirical analysis. Finally, section V concludes the paper.

I. The Companies[1]

A. Faro Technologies Inc (FARO)

FARO Technologies is an instrument company whose principle activities include design and develop portable 3-D electronic systems for industrial applications in the manufacturing system. The company's principal products include the Faro Arm, Faro Scan Arm and Faro Gage articulated measuring devices. It mainly operates in the United States and Europe.

B. FEI Company (FEI)

FEI is a leading scientific instruments company which develops and manufactures diversified semiconductor equipments including electron microscopes and beam systems. It operates in four segments: NanoElectronics, NanoResearch and Industry, NanoBiology and Service and Components. With a 60-year history, it now has approximately 1800 employees and sells products to more than 50 countries around the world.

C. Fidelity Southern Corp. (LION)

Fidelity Southern Corp. is one of the largest community banks in metro Atlanta which provides a wide range of financial services including commercial and mortgage services to both corporate and personal customers. It also provides international trade services, trust services, credit card loans, and merchant services. The company provides financial products

and services for business and retail customers primarily through branches and via internet.

D. NYSE/AMEX/NASDAQ Index

It is an index taken from the Center for Research in Security Prices (CRSP) which includes all common stocks listed on the NYSE, Amex, and NASDAQ National Market. The index is constructed by ranking all NYSE companies according to their market capitalization in the first place. They are then divided into 10 decile portfolios. Amex and NASDAQ stocks are then placed into the deciles based on NYSE breakpoints. The smallest and the largest firms based on market capitalization are placed into Decile 1 and Decile 10, respectively.

II. Data and Methodology

A. Data

Data for the three stocks and two decile indices in our study are all obtained from the Center for Research in Securities Prices database (CRSP) on both daily and monthly basis from January 2000 to December 2005. Returns are then computed on both basis, generating a total of 1507 daily observations and 71 monthly observations. The NYSE/AMEX/NASDAQ Index is CRSP Capitalisation-based so that Decile 1 and 10 represent the smallest and largest firms, respectively, based on market capitalisation. In addition, The Standard and Poors 500 Index (S&P 500) is used as a proxy for the market index. It is a valued-weighted index which incorporates the largest 500 stocks in US market. For comparison purposes, both continuously

compounded (log) returns and simple returns are reported, although the analysis is based on the result of the first one.

B. Methods

B. 1. Autocorrelation Tests

One of the most intuitive and simple tests of random walk is to test for serial dependence, i. e. autocorrelation. The autocorrelation is a time-series phenomenon, which implies the serial correlation between certain lagged values in a time series. The first-order autocorrelation, for instance, indicates to what extent neighboring observations are correlated. The autocorrelation test is always used to test RW3, which is a less restrictive version of random walk model, allowing the existence of dependent but uncorrelated increments in return data. The formula of autocorrelation at lag k is given by:

(1) where ρ_k is the autocorrelation at lag k ; r_t is the log-return on stock at time t ; and r_{t-k} is the log-return on stock at time $t-k$. A greater than zero indicates a positive serial correlation whereas a less than zero indicates a negative serial correlation. Both positive and negative autocorrelation represent departures from the random walk model. If ρ_k is significantly different from zero, the null hypothesis of a random walk is rejected.

The autocorrelation coefficients up to 5 lags for daily data and 3 lags for monthly data are reported in our test. Results of the Ljung-Box test for all lags up to the above mentioned for both daily and monthly data are also reported. The Ljung-Box test is a more powerful test by summing the squared autocorrelations. It provides evidence for whether departure for zero

autocorrelation is observed at all lags up to certain lags in either direction.

The Q-statistic up to a certain lag m is given by:

(2)

B. 2. Variance Ratio Tests

We follow Lo and MacKinlay's (1988) single variance ratio (VR) test in our study. The test is based on a very important assumption of random walk that variance of increments is a linear function of the time interval. In other words, if the random walk holds, the variance of the q th differenced value should be equal to q times the variance of the first differenced value. For example, the variance of a two-period return should be equal to twice the variance of the one-period return. According to its definition, the formula of variance ratio is denoted by:

(3) where q is any positive integer. Under the null hypothesis of a random walk, $VR(q)$ should be equal to one at all lags. If $VR(q)$ is greater than one, there is positive serial correlation which indicates a persistence in prices, corresponding to the momentum effect. If $VR(q)$ is less than one, there is negative serial correlation which indicates a reversal in prices, corresponding to the mean-reverting process.

Note that the above two test are also tests of how stock prices react to publicly available information in the past. If market efficiency holds true, information from past prices should be immediately and fully reflected in the current stock price. Therefore, future stock price change conditioned on past prices should be equal to zero.

B. 3. Griffin-Kelly-Nardari DELAY Tests

As defined by Griffin, Kelly and Nardari (2007), “ delay is a measure of sensitivity of current returns to past market-wide information”.^[2] Speaking differently, delay measures how quickly stock returns can react to market returns. The logic behind this is that a stock which is slow to incorporate market information is less efficient than a stock which responds quickly to market movements.

S&P 500 index is employed in delay test to examine the sensitivity of stock returns to market information. For each stock and decile index, both restricted and unrestricted models are estimated from January 2000 to December 2005. The unrestricted model is given by:

(4) where r_{it} is the log-return on stock i at time t ; r_{mt} is the market log-return (return for S&P 500 index) at time t ; $r_{m,t-k}$ is the lagged market return; α is the coefficient on the lagged market return; and k is the lag which is 1, 2, 3, 4 for the daily data and 1, 2, 3 for the monthly data. The restricted model is as follows which sets all to be zero:

(5) Delay is then calculated based on adjusted R-squares from above regressions as follows:

(6) An alternative scaled measure of delay is given by:

(7) Both measures are reported in a way that the larger the calculated delay value, the more return variation is explained by lagged market returns and thus the more delayed response to the market information.

III. Descriptive Statistics

A. Daily frequencies

Table I shows the summary statistic of daily returns for the three stocks and two decile indices. The highest mean return is for FARO (0.0012), whereas the lowest mean return is for NAN D10 (0.0000). In terms of median return, NAN D1 (0.0015) outperforms all the other stocks. Both the highest maximum return and the lowest minimum return (0.2998 and -0.2184, respectively) are for FARO, corresponding to its highest standard deviation (0.0485) among all, indicating that FARO is the most volatile in returns. On the other hand, both the lowest maximum return and highest minimum return (0.0543 and -0.0675, respectively) are for NAN D10. However NAN D10 is only the second least volatile, while the lowest standard deviation is for NAN D1 (0.0108). Figure 1 and 2 presents the price level of the most and least volatile index (stock). All the above observations remain true if we change from log-return basis to a simple return basis.

In terms of the degree of asymmetry of the return distributions, all stocks and indices are positively skewed, with the only exception of NAN D1. The positive skewness implies that more extreme values are in the right tail of the distribution, i. e. stocks are more likely to have times when performance is extremely good. On the other hand, NAN D1 is slightly negatively skewed, which means that returns are more likely to be lower than what is expected by normal distribution. In measuring the “peakedness” of return distributions, positive excess kurtosis is observed in all stocks and indices, also known as a leptokurtic distribution, which means that returns either cluster around the mean or disperse in the two ends of the distribution. All

<https://assignbuster.com/measuring-weak-form-market-efficiency-essay-samples/>

the above observations can be used to conclusively reject the null hypothesis that daily returns are normally distributed. What's more, results from Jarque-Bera test provide supportive evidence for rejection of the normality hypothesis at all significant levels for all stocks and indices.

B. Monthly frequencies

Descriptive statistics of monthly returns are likewise presented in Table II. Most of the above conclusions reached for daily returns are also valid in the context of monthly returns. In other words, what is the highest (lowest) value for daily returns is also the highest (lowest) for monthly returns in most cases. The only exceptions are for the highest value in median returns and the lowest value and standard deviation in minimum returns. In this situation, NAN D10 (0.0460) and FARO (0.1944) have the least and most dispersion according to their standard deviations, compared with NAN D1 and FARO in daily case. From above observation, we can see that decile indices are more stable than individual stocks in terms of returns. What's more, monthly returns have larger magnitude in most values than daily returns.

Coming to the measurement of asymmetry and peakedness of return distributions, only NAN D10 (-0.4531) is negatively skewed. However, the degree of skewness is not far from 0. Other stocks and index are all positively skewed with both FEIC (0.0395) and LION (0.0320) having a skewness value very close to 0. Almost all stocks and index have a degree of kurtosis similar to that of normal distribution, except that NAN D1 (8.6623) is highly peaked. This is also consistent with the results of JB p-values, based

on which we conclude that FEIC, LION and NAN D10 are approximately normal because we fail to reject the hypothesis that they are normally distributed at 5% or higher levels (see Figure 3 and 4 for reference).

However when simple return basis is used, FEIC is no longer normally distributed even at the 1% significant level. Except this, using simple return produces similar results.

IV. Results

A. Autocorrelation Tests

A. 1. Tests for Log>Returns

The results of autocorrelation tests for up to 5 lags of daily log>Returns and up to 3 lags of monthly log>Returns for three stocks and two decile indices from January 2000 to December 2005 are summarised in Table III. Both the autocorrelation (AC) and partial autocorrelation (PAC) are examined in our tests.

As is shown in Panel A, all 5 lags of FARO, FEIC and NAN D10 for both AC and PAC are insignificant at 5% level, except for the fourth-order PAC coefficient of FARO (-0.052), which is slightly negatively significant. On the contrary, NAN D1 has significant positive AC and PAC at almost all lags except in the fourth order, its PAC (0.050) is barely within the 5% significance level. The significant AC and PAC coefficients reject the null hypothesis of no serial correlation in NAN D1, thereby rejecting the weak-form efficiency. In terms of LION, significant negative autocorrelation coefficients are only observed in the first two orders and its higher-order coefficients are not statistically significant. Besides that, we find that all the stocks and indices have <https://assignbuster.com/measuring-weak-form-market-efficiency-essay-samples/>

negative autocorrelation coefficients at most of their lags, with the only exception of NAN D1, whose coefficients are all positive. The strictly positive AC and PAC indicates persistence in returns, i. e. a momentum effect for NAN D1, which means that good or bad performances in the past tend to continue over time.

We also present the Ljung-Box (L-B) test statistic in order to see whether autocorrelation coefficients up to a specific lag are jointly significant. Since RW1 implies all autocorrelations are zero, the L-B test is more powerful because it tests the joint hypothesis. As is shown in the table, both LION and NAN D1 have significant Q values in all lags at all levels, while none of FARO, FEIC and NAN D10 has significant Q values.

Based on above daily observations, we may conclude that the null hypothesis of no serial correlation is rejected at all levels for LION and NAN D1, but the null hypothesis cannot be rejected at either 5% level or 10% level for FARO, FEIC and NAN D10. This means that both LION and NAN D1 are weak-form inefficient. By looking at their past performance, we find that while NAN D1 outperformed the market in sample period, LION performed badly in the same period. Therefore, it seems that stocks or indices with best and worst recent performance have stronger autocorrelation. In particular, LION shows a positive autocorrelation in returns, suggesting that market-wide indices with outstanding recent performance have momentum in returns over short periods, which offer predictable opportunities to investors.

When monthly returns are employed, no single stock or index has significant AC or PAC in any lag reported at 5% level. It is in contrast with daily returns,

which means that monthly returns follow a random walk better than daily returns. More powerful L-B test confirms our conclusion by showing that Q statistics for all stocks and indices are statistically insignificant at either 5% or 10% level. Therefore, the L-B null hypothesis can be conclusively rejected for all stocks and indices up to 3 lags. When compared with daily returns, monthly returns seem to follow random walk better and are thus more weak-form efficient.

A. 2. Tests for Squared Log>Returns

Even when returns are not correlated, their volatility may be correlated. Therefore, it is necessary for us to expand the study from returns to variances of returns. Squared log>Returns and absolute value of log>Returns are measures of variances and are thus useful in studying the serial dependence of return volatility. The results of autocorrelation analysis for daily squared log>Returns for all three stocks and two decile indices are likewise reported in Table IV.

In contrast to the results for log>Returns, coefficients for FEIC, LION, NAN D1 and NAN D10 are significantly different from zero, except for the forth-order PAC coefficient (0. 025) for FEIC, the fifth-order PAC coefficient for LION (-0. 047) and third- and forth-order PAC coefficient for NAN D1 (-0. 020 and -0. 014, respectively). FARO has significant positive AC and PAC at the first lag and a significant AC at the third lag. The L-B test provides stronger evidence against the null hypothesis that sum of the squared autocorrelations up to 5 lags is zero for all stocks and indices at all significant levels, based on which we confirm our result that squared log>Returns do not follow a random walk.

Another contrasting result with that of log-returns is that almost all the autocorrelation coefficients are positive, indicating a stronger positive serial dependence in squared log-returns.

In terms of monthly data, only FEIC and NAN D10 have significant positive third-order AC and PAC estimates. Other stocks and indices have coefficients not significantly different from zero. The result is supported by Ljung-Box test statistics showing that Q values are only statistically significant in the third lag for both FEIC and NAN D10. This is consistent with the result reached for log-returns above, which says that monthly returns appear to be more random than daily returns.

A. 3. Tests for the Absolute Values of Log-Returns

Table V provides autocorrelation results for the absolute value of log-returns in similar manner. However, as will be discussed below, the results are even more contrasting than that in Table IV.

In Panel A, all the stocks and indices have significant positive serial correlation while insignificant PAC estimates are only displayed in lag 5 for both FARO and LION. Supporting above result, Q values provide evidence against the null hypothesis of no autocorrelation. Therefore, absolute value of daily log-returns exhibit stronger serial dependence than in Table III and IV, and autocorrelations are strictly positive for all stocks and indices.

Coming to the absolute value of monthly log-returns, only FEIC displays significant individual and joint serial correlation. NAN D1 also displays a significant Q value in lag 2 at 5% level, but it is insignificant at 1% level.

Based on the above evidence, two consistent conclusions can be made at this point. First of all, by changing ingredients in our test from log-returns to squared log-returns and absolute value of log-returns, more positive serial correlation can be observed, especially in daily data. Therefore, return variances are more correlated. Secondly, monthly returns tend to follow a random walk model better than daily returns.

A. 4. Correlation Matrix of Stocks and Indices

Table VI presents the correlation matrix for all stocks and indices. As is shown in Panel A for daily result, all of the correlations are positive, ranging from 0.0551 (LION-FARO) to 0.5299 (NAN D10-FEIC). Within individual stocks, correlation coefficients do not differ a lot. The highest correlation is between FEIC and FARO with only 0.1214, indicating a fairly weak relationship between individual stocks returns. However, in terms of stock-index relationships, they differ drastically from 0.0638 (NAN D10-FARO) to 0.5299 (NAN D10-FEIC). While the positive correlation implies that the three stocks follow the indices in the same direction, the extent to which they will move with the indices is quite different, indicating different levels of risk with regard to different stock. Finally, we find that the correlation between NAN D10 and NAN D1 is the second highest at 0.5052.

Panel B provides the correlation matrix for monthly data. Similar to results for daily data, negative correlation is not observed. The highest correlation attributes to that between NAN D10 and FEIC (0.7109) once again, but the lowest is between LION and FEIC (0.1146) this time. Compared with results in Panel A, correlation within individual stocks is slightly higher on average.

The improvement in correlation is even more obvious between stocks and indices. It implies that stock prices can change dramatically from day to day, but they tend to follow the movement of indices in a longer horizon. Finally, the correlation between two indices is once again the second highest at 0.5116, following that between NAN D10 and FEIC. It is also found that the correlation between indices improves only marginally when daily data are replaced by monthly data, indicating a relatively stable relationship between indices.

B. Variance Ratio Tests

The results of variance ratio tests are presented in Table VII for each of the three stocks and two decile indices. The test is designed to test for the null hypothesis of a random walk under both homoskedasticity and heteroskedasticity. Since the violation of a random walk can result either from changing variance, i. e. heteroskedasticity, or autocorrelation in returns, the test can help to discriminate reasons for deviation to some extent. The lag orders are 2, 4, 8 and 16. In Table VII, the variance ratio ($VR(q)$), the homoskedastic-consistent statistics ($Z(q)$) and the heteroskedastic-consistent statistics ($Z^*(q)$) are presented for each lag.

As is pointed out by Lo and MacKinlay (1988), the variance ratio statistic $VR(2)$ is equal to one plus the first-order correlation coefficient. Since all the autocorrelations are zero under RW1, $VR(2)$ should equal one. The conclusion can be generalised further to state that for all q , $VR(q)$ should equal one.

According to the first Panel in Table VII, of all stocks and indices, only LION and NAN D1 have variance ratios that are significantly different from one at <https://assignbuster.com/measuring-weak-form-market-efficiency-essay-samples/>

all lags. Therefore, the null hypothesis of a random walk under both homoskedasticity and heteroskedasticity is rejected for LION and NAN D1, and thus they are not weak-form efficient because of autocorrelations. In terms of FARO, the null hypothesis of a homoskedastic random walk is rejected, while the hypothesis of a heteroskedastic random walk is not. This implies that the rejection of random walk under homoskedasticity could partly result from, if not entirely due to heteroskedasticity. On the other hand, both FEIC and NAN D10 follow random walk and turn out to be efficient in weak form, corresponding exactly to the autocorrelation results reached before in Table III.

Panel B shows that when monthly data are used, the null hypothesis under both forms of random walk can only be rejected for FARO. As for FEIC, the random walk null hypothesis is rejected under homoskedasticity, but not under heteroskedasticity, indicating that rejection is not due to changing variances because $Z^*(q)$ is heteroskedasticity-consistent.

As is shown in Panel A for daily data, all individual stocks have variance ratios less than one, implying negative autocorrelation. However, the autocorrelation for stocks is statistically insignificant except for LION. On the other hand, variance ratios for NAN D1 are greater than one and increasing in q . The above finding provides supplementary evidence to the results of autocorrelation tests. As Table III shows, NAN D1 has positive autocorrelation coefficients in all lags, suggesting a momentum effect in multiperiod returns. Both findings appear to be well supported by empirical evidence. While daily returns of individual stocks seem to be weakly negatively correlated (French and Roll (1986)), returns for best performing market indices such as NAN D1 <https://assignbuster.com/measuring-weak-form-market-efficiency-essay-samples/>

show strong positive autocorrelation (Campbell, Lo, and MacKinlay (1997)).

The fact that individual stocks have statistically insignificant autocorrelations is mainly due to the specific noise contained in company information, which makes individual security returns unpredictable. On the contrary, while the positive serial correlation for NAN D1 violates the random walk, such deviation provides investors with confidence to forecast future prices and reliability to make profits.

C. Griffin, Kelly and Nardari DELAY Tests

The results of delay test for the three stocks and two decile indices over the January 2000 to December 2005 period are summarised in Table VIII. We use lag 1, 2, 3, 4 for the daily data and 1, 2, 3 for the monthly data.

As is presented in Panel A for daily returns, Delay_1 value for NAN D10 is close to zero and hence not significant, while NAN D1 has the highest delay among all stocks and indices. The rank of delay within individual stocks seems to have a positive relationship between size and delay value, by showing that delay of LION, the stock with smallest market capitalization is lowest, while the delay of FEIC, the stock with largest market capitalization is highest. It seems to contradict with the Griffin, Kelly and Nardari (2006) study, which says that there is an inverse relationship between size and delay. One possible explanation for that is that delay calculated by daily data on individual firms is noisy.

The scaled measure Delay_2 produces consistent conclusion but with higher magnitude in values. Delay_2 values are very different from zero for FARO,

FEIC, LION and NAN D1. The largest increase in value is seen in FARO from 0. <https://assignbuster.com/measuring-weak-form-market-efficiency-essay-samples/>

0067 for Delay_1 to 0.7901 for Delay_2. Therefore, Griffin, Kelly and Nardari delay measure is preferable, because the scaled version can result in large values without economic significance.

As is displayed in Panel B, employing monthly data also leads to higher Delay_1 values, indicating that more variation of monthly returns are captured by lagged market returns and hence monthly returns are not as sensitive as daily returns to market-wide news. However, an inverse relationship is found this time between delay and market value of individual stocks. Therefore, monthly data provides consistent result to support Griffin, Kelly and Nardari (2006) result as one would normally expect larger stocks to be more efficient in responding to market. Similar to the result for daily data, scaled measure once again produces higher values than its alternative but it provides the same results.

V. Conclusion

The main objective of this paper is to test weak-form efficiency in the U. S. market. As is found by selected tests, NAN D10 and FEIC provide the most consistent evidence to show weak-form efficiency, while the deviation from random walk is suggested for other stocks and indices, especially for NAN D1 and LION. It indicates that security returns are predictable to some degree, especially for those having best and worst recent performance.

The three autocorrelation tests provide different results in terms of daily returns. While the null hypothesis of random walk is rejected for NAN D1 and LION based on log-returns, it is rejected for all stocks and indices based on both squared and absolute value of log-returns, indicating that return

variances are more correlated. On the other hand, results in the context of monthly returns are consistent. Monthly returns follow a random walk much better than daily returns in all three tests. Most evidently, the autocorrelation test fails to reject the presence of random walk for all stocks and indices when monthly log-returns are employed.

The variance ratio tests provide supportive evidence for autocorrelation tests. Both tests find that in terms of daily return, NAN D1 and LION show a significant return dependence. In particular, variance ratios for NAN D1 are all above one, corresponding to its positive AC and PAC coefficients, thus implying positive autocorrelation in returns. What's more, individual stocks have variance ratios less than one with FEIC and FARO both being insignificant. The above evidence conclusively suggest that while individual stock returns are weakly negatively related and difficult to predict, market-wide indices with outstanding recent performance such as NAN D1 tend to show a stronger positive serial correlation and thus offer predictable profit opportunities.

The evidence regarding delay tests is consistent with earlier findings to a large extent. NAN D1 has highest delay in both daily and monthly cases, implying an inefficient response to market news. In the context of monthly log-returns, delay values for individual stocks rank inversely based on market capitalisation with larger cap stocks having lower delay, suggesting that small stocks do not capture past public information quickly and are thus inefficient.

Finally, deviation from a random walk model and thus being weak-form inefficiency is not necessarily bad. In fact, investors should be rewarded a certain degree of predictability for bearing risks. Therefore, future research could be done by incorporating risk into the model.

[1] Company information is mainly obtained from Thomson One Banker database.

[2] Griffin, John M., Patrick J. Kelly, and Federico Nardari, 2006, Measuring short-term international stock market efficiency, Working Paper